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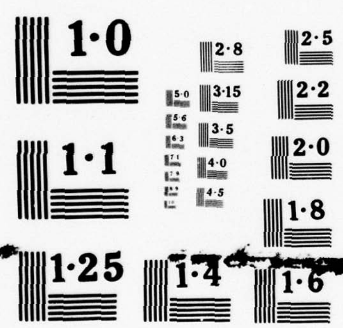
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Five Year Plan for Space Test Program

Prepared by

H. E. FRANK WANG, R. G. KNAUSS
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28 August 1978

Prepared for

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AIR FORCE SYSTEMS COMMAND
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Advanced Programs Division

THE AEROSPACE CORPORATION

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Many schedule and cost factors were evaluated in the development of this Five Year Plan. Schedules used in the document are representative of a large group that were constructed to demonstrate approaches and program impacts and do not imply final plans or approval for implementation. Likewise, the STP missions noted here do not imply experiment flight recommendation or mission approval. In addition, each mission would consist of a group of experiments but is given the name of the primary experiment for identification only.

Mission cost information was also developed for planning purposes to demonstrate relative economic advantages of different hardware and mission concepts and scheduling impacts. Cost data were collected from existing documents, pre-released guides, and contractor estimates. Detailed mission and common support equipment costs have been deleted since these costs were used for Air Force budgeting and are considered sensitive.

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Examined available systems, services, and test methods afforded by the Shuttle to conduct space experiments. Assumed pathfinder role for DoD towards the full utilization of the Shuttle by developing (1) Common Support Equipment for astronaut assisted Sortie flights, and (2) cost effective approaches for primary and secondary free-flying spacecraft.

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FIVE YEAR PLAN FOR SPACE TEST PROGRAM

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EXECUTIVE SUMMARY

SCOPE AND OBJECTIVES

The Program Management Directive (PMD R-S 2140(7)/PE63402F, 31 March 1978) directed the Space Test Program (STP) to develop a plan, covering the first five years of Shuttle Operations, for meeting the needs of STP experiments using the Shuttle. The broad objective was to define cost-effective ways to conduct space experimentations in terms of reducing cost and shortening the time from experiment inception to data return. The specific objective was to define a method of implementation to accomplish the broad objective.

STUDY APPROACH

In generating the plan, STP examined the available systems, services, and test methods afforded by the Shuttle. These include standard satellites, recovery of satellites, manned operations, use of the Shuttle as a laboratory, and tethered flights. For STP, these capabilities are of great value since the program supports research, development, and space test that encompass new methods, technology, and innovations. The Five Year Plan assumes that STP plays a pathfinder role for the Department of Defense (DoD) towards the full utilization of the Shuttle. However, the plan is also guided by an orderly and prudent approach in taking advantage of the astronaut capabilities and the new testing methods. In particular, a prudent approach to the development of equipment supporting the manned laboratory operations is embodied in this Five Year Plan.

The plan is based on STP experiment requirements, present and projected. For convenience, the experiments are categorized as sortie or free-flyer. On a sortie mission, the experiment equipment remains in the Shuttle bay and is operated either by automatic control or by the astronaut during the short time the Shuttle is on orbit. A free-flyer is a

satellite separated from the Shuttle and on orbit for an extended period. Since the sortie flight mode is an important new concept, it constitutes a major portion of this Five Year Plan.

SORTIE MISSIONS

Experiment Requirements

Current STP experiments designed for sorties and using an astronaut are fewer in number than free-flyers since most of the presently conceived experiments were proposed years ago. Some free-flyer experiments can be converted to fly as sorties with some modifications of the experiment design and objectives. When the conversion is done, the ratio of free-flyer experiments to sortie experiments stands at approximately 2 to 1.

As the Shuttle operations mature and prove advantageous as a space laboratory, more STP sortie experiments are expected. Here, the STP role is seen to be one of influencing the experiment design and of providing support equipment common to all sortie and manned operations.

Benefits and Constraints

The study showed that benefits can be derived from sortie missions. Figure ES-1 illustrates the sortie flight costs versus free-flyer flight costs. The flight cost includes all costs to support a mission by STP except the Shuttle transportation cost which is budgeted for by the SAMSO Launch Vehicle Program Office. Depending on the mission requirements, a free-flyer primary mission costs between \$40 million and \$60 million while a single sortie costs approximately \$15 million. For a piggyback secondary experiment, the costs are on the order of \$8 million and \$4 million respectively. However, many experiments require more than one sortie flight (multi-sortie) to collect sufficient data to fulfill program objectives. A general conclusion is that one free-flyer cost is comparable to the cost of three or four sortie flights for the large system development missions.

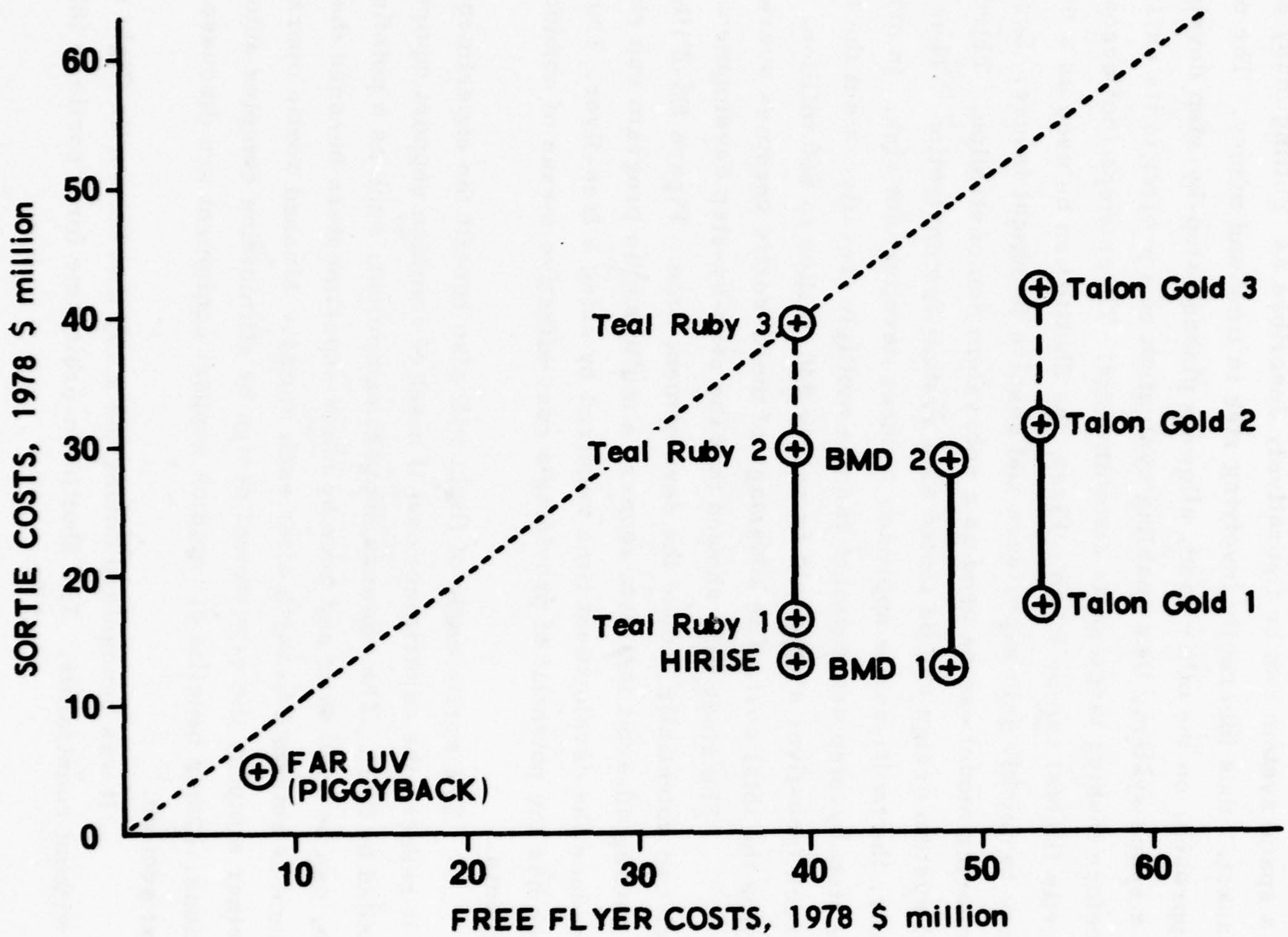


Figure ES-1. Free-Flyer vs. Sortie Costs

The multi-sortie approach is an advantage rather than a disadvantage. The conventional free-flyer approach to research and development of a space system can be figuratively described as "putting many eggs in one basket," thus inherently involving risk in time and money. The multi-sortie approach, on the other hand, allows a planned step-by-step development of a space system, thus enabling evaluation of a project in its early stages before making large scale commitments. Three steps (not necessarily three sortie flights) can be taken. First, the Shuttle can be used as a manned laboratory to quickly gain experience and resolve technical issues. Second, an engineering model can be used as a subsystem demonstration. Third, the final system design can be tested as a system demonstration. Thus, inherently, the multi-sortie approach reduces development risk. In principle, the step-by-step development can use multiple free-flyers but the flight cost of each free-flyer step would be nearly $40 million to $60 million, thus multiplying the total cost. The advantage of multi-sortie becomes overwhelming.

The study also showed that the step-by-step development approach can potentially reduce the development time. Figure ES-2 illustrates that by getting on-orbit test data sooner, a multi-sortie program can significantly reduce the development time required by using a free-flyer. Thus, this approach has the potential of providing a cost-effective means of conducting experiments.

The sortie mode of flight will also benefit the experimenters in that it reduces the experiment cost if a set of common support equipment is provided by STP. The common support equipment, such as a pointing system, can be used over and over by many experimenters because the equipment is returned to earth after each sortie. Manned sortie operations can further simplify the experiment design by eliminating complex automated operations. Other benefits of common support equipment are discussed in the next section.

It was recognized during the study that the sortie flight mode is not without constraints. The Shuttle on-orbit time for a sortie is initially

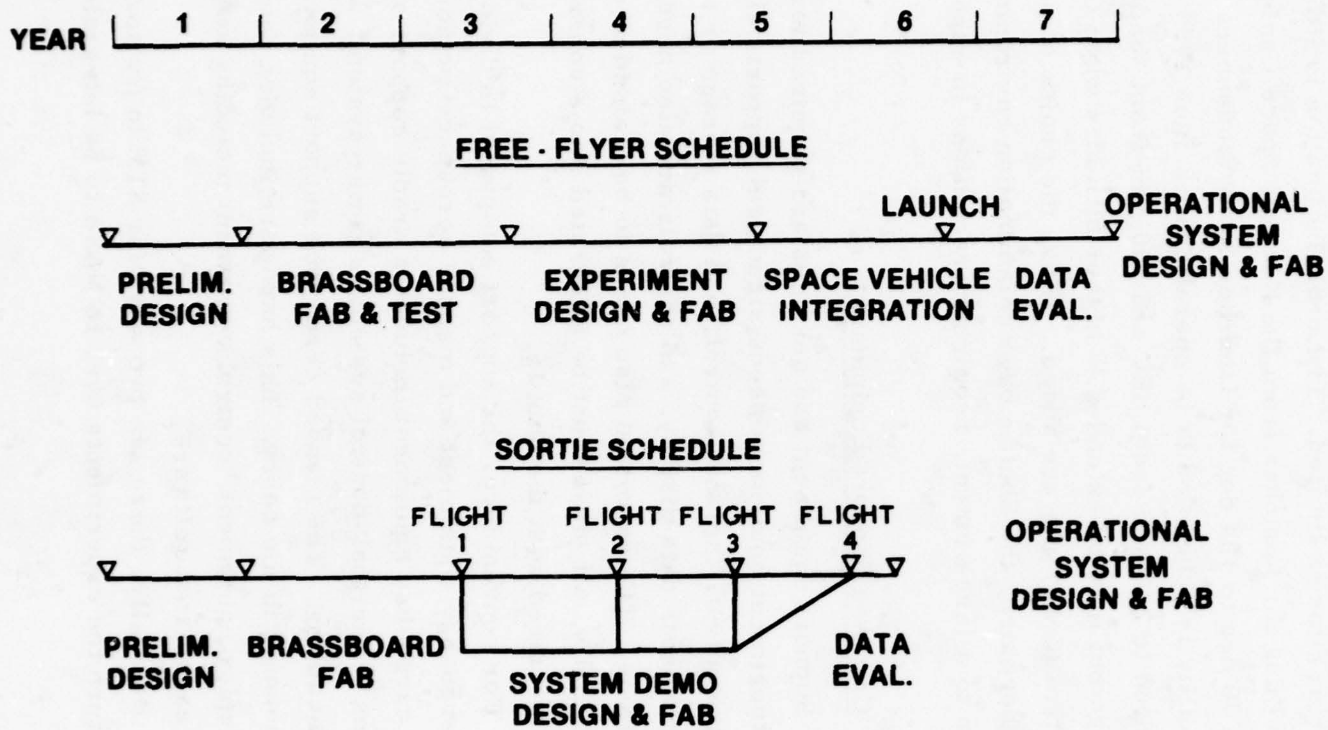


Figure ES 2. Benefits of Step-by-Step Development

seven days, and may be extended as long as one month or two at most. Thus the data gathering time is limited. The orbit inclination is limited to between 28.5 deg and 57 deg for launches from the Kennedy Space Center (KSC) and extended from 70 deg to 104 deg for launches from Vandenberg AFB. (The Vandenberg facility is scheduled to be operational in June 1983.) The orbit altitude is limited to 250 nmi from KSC and 200 nmi from Vandenberg for a 30,000-lb cargo but may be extended to higher altitudes when Orbit Maneuver System (OMS) kits are added. Thus, the choice of orbit is also limited. Furthermore, the Shuttle bay contamination environment is presently unknown to a large extent, requiring precautions in experiment design.

Common Support Equipment

Support equipment and services are required for a sortie flight. The experiment equipment needs structural support, electrical power, attitude control, thermal control, and data storage or transmission. Computing equipment, data display, and controls are also needed for manned operations. The astronaut also needs to be trained to operate each experiment. Finally, all these must be integrated into a coherent system and properly interfaced with the Shuttle.

For convenience, the support equipment is divided into two categories: cargo-bay equipment and manned aerospace support equipment (MASE). The cargo-bay equipment includes a cradle support structure, a pointing system, a thermal-control system, a power system, a data system, and associated cabling. The manned aerospace support equipment consists of hardware mounted in the cabin. This hardware includes computer, data storage and display equipment, control equipment including keyboard and joy stick, and associated software.

Basically, there are two ways for STP to fly sortie payloads. One way is to turn the experiments over to NASA to be integrated into the

Spacelab missions and the other is to first integrate the experiments into a complete cargo element which is then integrated into the Shuttle flight system as an independent package. Although the required support equipment and services are available from the Shuttle if STP follows the former route, they are quite time consuming (on the order of three years for the end-to-end integration process), involve a large number of interface agents (other experimenters and the four-level integration contractors), and involve complex security measures for classified experiments. The latter route, on the other hand, presents a more manageable alternative and can be implemented through a set of common support equipment.

The common support equipment essentially creates a "buffer" between the Shuttle and DoD experiments by being responsive to security requirements, circumventing the complex, segmented Spacelab integration process, increasing isolation from other Shuttle payloads, and reducing the number of interfacing agents. By doing so, STP would be able to provide a quick reaction service to some experimenters. These experimenters desire quick reaction to speed up infusion of technology into space systems. This can be done by space testing ideas quickly or testing more ideas in a given time. Thus, the cargo-bay support equipment satisfies the broad objective of shortening the time from experiment inception to data return.

The common support equipment also facilitates the utilization of the astronaut capabilities. Astronauts are capable of performing interactive operations with the experiments such as making visual observations, editing data, pointing instruments, assembling structures, deploying or retrieving satellites, diagnosing failures, and making repairs. Their greatest utility, of course, is their ability to react in real time to unexpected situations such as identification of targets of opportunity and adjustments of

instruments, failure diagnosis, and repair. They are also valuable in performing real-time iterative operations with ground personnel in the conduct of the experiment. To perform these functions, they must be provided with sufficient equipment. The manned aerospace support equipment fulfills this need. They must also be provided with adequate training. STP plans to provide training equipment and instructions for operation of the manned aerospace equipment in conjunction with required experiment operations. It is envisioned that the experimenter will provide the payload specialist to go along with the flight crew and that NASA will provide training for life support and emergency routines.

Acquisition Plan for Common Support Equipment

The STP acquisition plan is guided by a prudent study philosophy. Figuratively speaking, STP recommends the "crawl before walk" approach. The previous section described the components making up the common support equipment at its full capability as presently envisioned. For the cargo bay support equipment, STP proposes to initially procure a cradle and interface equipment for interfacing with the Orbiter power, thermal, and data systems. The first sortie mission could be BMD which needs no pointing system since the experiment sensor package is either mounted on a gimbal provided by the experimenter or hard-mounted on a pallet. The experiment could provide its own signal processor, data processor, servo electronics, and thermal control. Data would be interleaved with the Orbiter system and downlinked via the Tracking and Data Relay Satellite System (TDRSS). The manned aerospace equipment needed for the first sortie mission would be limited because a payload specialist would be required only to monitor instrumentation status, to control test sequence, and to perform corrective tasks in case of malfunctions. The experimenter would also provide a control panel that would consist of the most needed equipment and thus allow STP to build up the manned aerospace support equipment in a gradual fashion. The design of the common support

equipment, however, would take into consideration the add-on equipment so that the upgrading could be smoothly accomplished. The upgrading would begin after the first sortie mission.

For the second sortie mission, such as HIRISE, a pointing system could be added and the manned operation could be more extensive as might be required by the experiment. Thus, the common support equipment would be upgraded to meet these requirements. Requirements for the third mission and beyond would eventually enable the upgraded common support equipment to reach its full capability. This phased development program is reflected in the proposed schedule and budget.

FREE-FLYER MISSIONS

A free-flyer is a self-sufficient satellite separated from the Shuttle and usually transferred to a different orbit (inclination and altitude) by an orbit transfer stage. It can be left on orbit for an indefinite period of time or recovered by the Shuttle. In the past ten years, STP has built dedicated spacecraft when required, converted existing spacecraft to fit a specific mission, and also piggybacked experiments on other programs. The same approach will be followed in the Shuttle era. Using standard satellites and standard orbit transfer stages, modifying existing spacecraft, and utilizing secondary space on other programs are effective ways to reduce mission costs. STP will continue to exploit these opportunities. Examples of using existing equipment and piggyback concepts are given in Figures ES-3 and ES-4 respectively.

The free-flyer mission provides the experiments with long on-orbit time to observe relatively infrequent events and to obtain full seasonal coverage. It also provides orbit environments not obtainable by a sortie flight. However, it is usually a much more expensive mission than sortie.

Currently, a large portion of the STP funds is consumed by large development programs for dedicated free-flyer missions. As a result, few space environment research experiments are scheduled for flight.

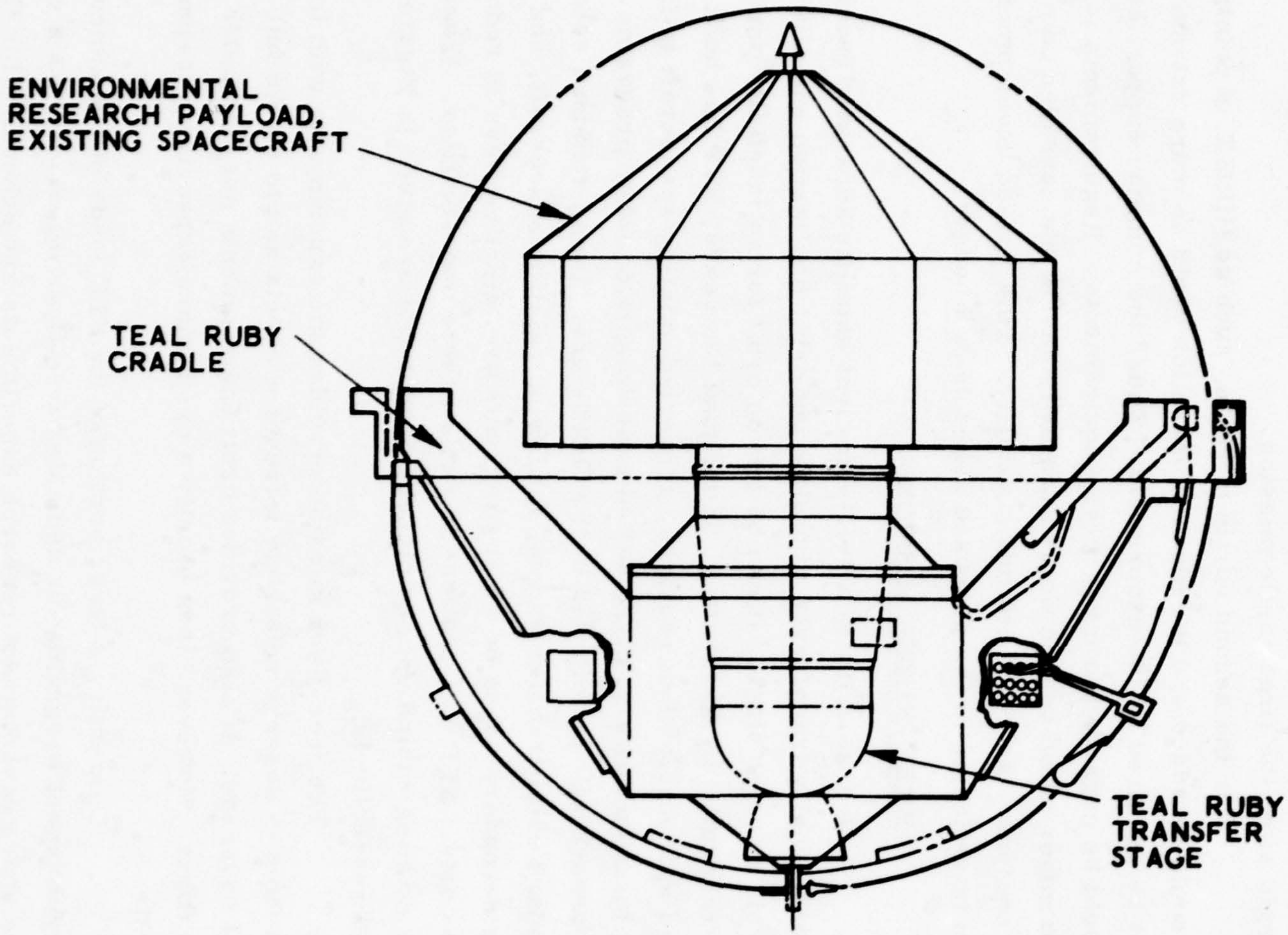


Figure ES-3. Approach for Using Existing Equipment

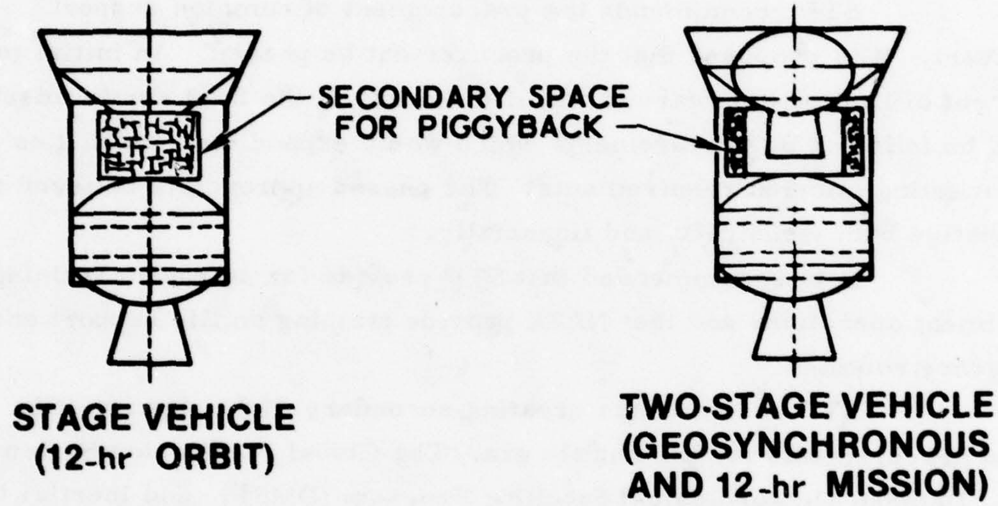


Figure ES-4. Piggyback Concepts

It is believed that the need to continue probing the space environment still exists, particularly in the areas of improved understanding of the environmental effects on communications, surveillance, and survivability. This need is considered in this Five Year Plan and reflected in the proposed program.

RECOMMENDATIONS AND IMPACTS

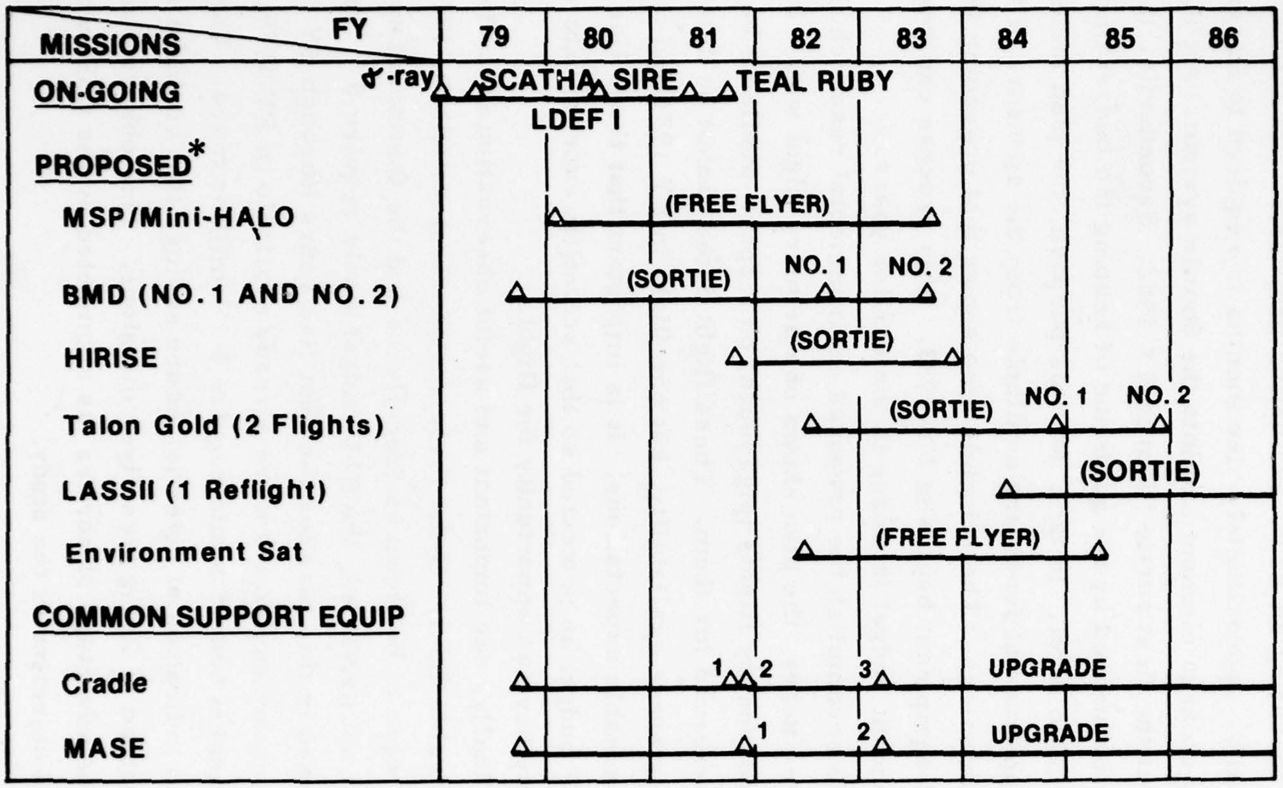
STP recommends the procurement of common support equipment. It is proposed that the procurement be phased. An initial procurement of limited hardware to fulfill the needs of the first sortie mission should be followed by procurements which would expand the capabilities while meeting mission requirements. The phased approach is believed to be effective both technically and financially.

It is recommended that STP provide for astronaut training on experiment operations and that NASA provide training on life support and emergency routines.

STP recommends creating secondary flight opportunities in new procurements for the Shuttle era. The Global Positioning System (GPS), Defense Meteorological Satellite Program (DMSP), and Inertial Upper Stage (IUS) are good candidates.

STP recommends planning and budgeting for an environmental research spaceflight every two or three years. The configuration depicted in Figure ES-3 could be one such satellite.

The proposed schedule is given in Figure ES-5. The MSP/Mini-HALO mission schedule established prior to this study is not perturbed in this plan. The launch dates for the proposed missions are a year or more later than those advocated by the experimenters. This is primarily dictated by the earliest date by which the common support equipment can be procured by STP. A period of performance of two years is considered minimum to procure the first two cradles with Shuttle interface units and



*These missions are assumed for purposes of budget planning and CSE procurement strategy

Figure ES-5. STP Schedule

the first set of manned aerospace support equipment to support the first flight. Some up-front time (approximately one year) is required for studying requirements, generating an RFP, evaluating proposals, and selecting a contractor. Finally, approximately nine months is required to integrate the experiments into a cargo element and into the Shuttle system. All these considerations put the first sortie flight in FY 1982. Secondarily, the launch dates are influenced by the guideline of keeping the budget impact down to a manageable level. In fact, for this purpose, the plan further assumes that supplemental funds are available from the sponsors of the first two sortie missions. The schedule also shows that upgrading the common support equipment begins in FY 1983. This process can begin earlier with attendant budget increase in the earlier years.

To accomplish the proposed environmental research flights every two or three years, the plan shows one primary flight with a launch date in FY 1985 and secondary flights (piggyback) on a space-available basis with a small budget reserved for them. These flight dates cannot be determined prior to exploring space availability, but one flight in FY 1981 and one in FY 1983 are reasonable expectations. It is important that these line items in the proposed STP budget be protected so that scientific experiments of relatively low priority have an opportunity for flight.

Finally, one important and useful observation is made and this is shown in Table ES-1. If the three sortie missions (BMD, HIRISE, and Talon Gold) were to be flown as free-flyers and the Common Support Equipment (CSE) not produced, the STP budget would require \$ [1] million more than proposed in this plan for the next five years (through FY 1984). If the common support equipment were already available in FY 1979, the all free-flyer mission budget would require \$ [1] million more. The last comparison is an indication of potential future savings that could be made by flying sorties instead of flying free-flyer missions. This observation puts in perspective the advantage of sorties (as augmented by the CSE) which fulfills the broad objective of the study.

[1] As noted on the inside front cover, cost figures have been deleted.

Table ES-1. Free-Flyer vs. Sortie Cost Comparison[a]

Budget	Estimates in Then Year $ Million						
	79	80	81	82	83	84	Total
Budget as Proposed with Sorties and CSE Costs							
Budget to Perform Experiments as Proposed But with All Free-Flyers							
Budget as Proposed without Cost of CSE							

[a]As noted on the inside front cover, cost figures have been deleted.

1. INTRODUCTION

The Space Test Program (STP) was tasked by the Air Force Systems Command (AFSC) in December 1977 to develop a plan meeting the needs of DoD STP experiments using the Shuttle during the first five years of Shuttle operations. The task was later formally documented in the Program Management Directive (Ref. 1-1). The broad objective was to study and define cost-effective ways to conduct space testing in the future. It requested that the study address whether it is reasonable and possible to conduct experiments using the Shuttle as a laboratory. It also requested that STP address whether there are methods that should be implemented for shortening the time to launch and reducing mission cost. Support equipment for sortie missions should be analyzed and compared, both technically and in terms of cost effectiveness. Comparative studies for spacecraft approaches should also be addressed for those experiments that require free-flying satellites.

STP began developing the Five Year Plan by reviewing available systems/services in the Shuttle era and by reviewing the DoD experiment requirements, both present and projected. The available systems reviewed include all those offered by the Shuttle: the Spacelab, the Instrument Pointing System being developed by the European Space Agency (ESA) and by the National Aeronautics and Space Administration (NASA), the Remote Manipulator System (RMS), the "Getaway-Special," the Long Duration Exposure Facility (LDEF), and the Inertial Upper Stage (IUS). A brief description of these systems is given in Appendix A. Additionally, applicable systems that were not specifically developed as a part of the Shuttle system were also reviewed. As there are many such systems, only those which have potential applications in the immediate five years are briefly described in Appendix A. These are the Multimission Modular Spacecraft (MMS) and the Satellite Control Section (SCS) spacecraft. The available services

reviewed include Shuttle utilities and the flight crew, which are also briefly described in Appendix A. The brief descriptions provide only an overview; more detailed information can be found in the sources listed in the bibliography.

The DoD experiment requirements were reviewed for current experiments and also projected for future experiments. The review focused on determining whether the experiments would require a free-flyer mission or a sortie mission, and if sortie, whether they would require tethering or tandem operations and whether they should be augmented by an astronaut. (On a sortie mission, the experiment remains in the Shuttle bay and is operated either by automatic control or the flight crew during the short time the Shuttle is on orbit. On a free-flyer mission, a satellite is separated from the Shuttle and remains on orbit for an extended period of time.) A brief summary of the review is given in Appendix B.

Following the review of available systems/services and experiment requirements, the study addressed how best these available systems and services could be utilized to meet the experiment requirements and what would be the best methods for implementation. These issues and proposed solutions form the main body of this Five Year Plan document. For convenience, they are divided into two sections, one discussing sortie missions and one discussing free-flyer missions. In the section on sortie missions, the concept of step-by-step development using multiple sorties is advanced. Next, astronaut utility is described and the need for common support equipment is detailed. Finally, the STP procurement approach for required equipment is presented. In the section on free-flyer missions, the needs for creating secondary space and for an environmental research satellite are presented along with potential use of standard and existing spacecraft. Recommendations as a result of the study are then summarized and the impacts on schedule and budget assessed.

Throughout the study, STP was guided by a self-imposed philosophy that utilization of the Shuttle's full capability should be approached

in an orderly, prudent fashion. This philosophy is considered advisable in view of the many uncertainties inherent in the current NASA and DoD plans and procedures. It is evident in the STP plan for the development of common support equipment needed to take advantage of the sortie test method and the astronaut. On the other hand, STP can play a "pathfinder" role for the DoD, particularly, in the area of utilizing astronaut capabilities for experiment operations. This role is reflected in the Five Year Plan.

2. SORTIE MISSIONS

2.1 FEATURES

The fundamental use of Shuttle Orbiter as a manned laboratory will be for the sortie, or short duration captive flight. While the Orbiter is sized to provide sufficient life support systems for seven days, extended missions are possible with inclusion of additional life support kits. A number of other factors also influence the desirability and economics of longer flights, such as orbit, payload objectives, crew activities, and additional crew training requirements.

The benefits derived by use of the manned sortie flight are many. The potentially greatest advantage is the astronaut capability: use of human intellect to make decisions and observations in real time and perform other tasks on board as described in a later section of this report. The recovery of flight equipment will reduce manufacturing costs and promote standardization of interfaces. One of the beneficial effects of standardizing will be to increase the probability of mission achievement. Reuse of equipment and procedures will allow shorter time from experiment conception to flight and data return.

The use of sorties, of course, will not replace the role of free-flying research and development missions. Experiment requirements, short flight durations, economic and technical limitations to orbit altitude and inclination, orbiter bay contamination, and fields-of-view (a function of Orbiter payload mix) must all be considered in the mission plan for a specific experiment. The Shuttle on-orbit time planned for an STP sortie will be initially limited to seven days, but it may be extended as long as a month or two in the future. Orbit inclination is limited to between 28.5 deg and 57 deg for launches from Kennedy Space Center (KSC) and extended from 70 deg to 104 deg for launches from Vandenberg AFB. Orbit altitude is limited to 250 nmi from KSC and 200 nmi from Vandenberg AFB for a 30,000-lb cargo but may be extended to higher altitudes if Orbit Maneuver System (OMS) kits are added.

Typically, a number of factors can be traded before establishing whether an experiment should be flown as a sortie or free-flyer. The schedule, cost, and mission risk trades between sortie and free-flyer are straightforward and easily made. Trades considering design, test, integration, and launch costs, experiment concept-to-flight time, and potential risk to successful mission completion are generally in favor of the sortie. Mission performance trades are not always so obvious and these are the ones that must be made before any mission can be accomplished in the most economical manner. Mission performance trades are those that relate desired scientific objectives to methods of accomplishment. Orbit parameters, environments, data collection and other experiment services are all directly related to these objectives and principally controlled by them. For this reason, the first (and most important) steps to be made in mission performance trades must be made with the experimenter and the STP working together. Some of the basic coordination steps with the experimenter, including the performance of tradeoff studies, are given in Appendix C. As conceptual experiment work proceeds, one question should be repeatedly asked: How can the experiment objectives be accomplished by a sortie? Only by answering this question prior to firmly establishing objectives and experiment implementation can the full utilization of a sortie be realized.

The following sections will further address the question of sortie modes of experiment flight and discuss the alternative means for the STP to provide required supporting services, including mechanical support cradle, electrical interfaces, and tools for the use of the astronauts.

2.1.1 Cost Comparisons of Sorties and Free-Flyer Missions

Cost estimations were made of several potential STP missions to demonstrate comparisons between sortie and free-flyer approaches to space test. Two of the experiments (BMD and HIRISE) were developed as sortie missions while the development of the third (Talon Gold) is presently under consideration. There appears to be no basic reason why scientific objectives of all

three experiments could not be achieved by either the sortie or free-flyer modes of test flight. It was further assumed that the HIRISE mission objectives could be reached with a single sortie or free-flyer, that BMD would require two sorties but could be accomplished with a single free-flyer, and that Talon Gold could require up to three sorties as opposed to a single free-flyer. The cost elements and their estimated values for each of the flights are summarized in Table 2-1. No experiment development or fabrication costs or STS transportation charges were included in these estimates. Additionally, no development or fabrication costs are included for sortie support equipment since they would be reused on many flights. In this case, cradle costs are for Orbiter bay and astronaut interface equipment refurbishment required prior to each flight.

Spacecraft and experiment integration costs are based upon STP experience accumulated in the past ten years, including the Teal Ruby and SIRE contracts. Shuttle integration cost is expected to be the second largest cost item — only preceded in magnitude by spacecraft development. The costs used in the table are based on assumptions that integration costs for repeated or similar flights will be greatly reduced from initial sortie costs, as shown for the Talon Gold mission. This assumption was not used for the BMD mission because sufficient differences exist between the two sortie flights (Ref. 2-1). Discussions with the Space Transportation System (STS) Program Office at SAMSO were held to review plans and cost estimates for other programs; however, the Teal Ruby mission is the only actual data point at this time. The Shuttle integration costs used reflect the reduction expected from the STP proposed integration methods, which are detailed in subsection 2.3.

Nonstandard Shuttle services include costs for an additional six days on orbit based on a NASA correspondence (Ref. 2-2). The astronaut training cost is also based on this correspondence. On-orbit services cover data dissemination to experimenters following reception by the ground station; the costs are based on STP experience.

Table 2-1. Sortie vs. Free-Flyer Cost Comparisons[a]

Cost Elements	Missions/Estimates in 1978 $ Million								
	HIRISE		BMD			Talon Gold			
	Free-Flyer	Sortie	Free-Flyer	Sortie No. 1[b]	Sortie No. 2[b]	Free-Flyer	Sortie No. 1[b]	Sortie No. 2	Sortie No. 3
Spacecraft		-		-	-		-	-	-
Special Requirements (security and pointer)	-		-	-		-			
Cradle									
Experiment Integration									
Upper Stage	-	-	-	-	-		-	-	-
Shuttle Integration									
Nonstandard Shuttle Services (6 additional days in orbit)	-		-			c			
On-orbit Services									
Astronaut Training	-		-			-			
Total									
Free-Flyer Totals									
Sortie Mission Totals									

[a] As noted on the inside front cover, cost figures have been deleted.

[b] Two Cradles Required

[c] Sortie Targets

Data from Table 2-1 are also plotted in Figure 2-1. In the figure, two additional sortie missions (Teal Ruby and Far UV) are included for comparison although they are not a part of the Five Year Plan study. As seen from Figure 2-1, as well as from Table 2-1, a single sortie flight is always cheaper than a free-flyer. Typically, a free-flyer may cost as much as three or four sorties. Basically, the cost difference stems from the fact that a free-flyer requires a spacecraft to provide power, attitude control, telemetery, and structure/thermal support for the experiments while a sortie draws these supports from the Orbiter and the reusable common support equipment.

Under current policy, the STS transportation cost is budgeted by the STS Program Office and thus is not considered a cost item for STP. From the overall DoD point of view it is useful for this cost item to be included in the comparison. Transportation cost was estimated for the three proposed missions and the comparison is shown in Table 2-2. These charges are based on established cost equations formulated by NASA and are determined by the larger cost as calculated for pro rata launch weight or length. An average Orbiter launch weight of 37,300 lb was used for the estimates. Inclusion of the transportation cost does not alter the conclusion drawn above.

2.1.2 Multi-Sorties

The logical extension of the Shuttle sortie is the development of a planned series of sorties to obtain experiment objectives in a quicker and more cost-effective manner than can be obtained by other means. The multi-sortie mission has many significant benefits, particularly for research and development experiments as explained in the following paragraphs.

2.1.2.1 Large System Development

Prior to the complete demonstration of state-of-the-art sensors or other research instrumentation, it is necessary to complete extensive developmental tasks such as assessing backgrounds at various wavelengths, measuring power spectral densities in wavelength bands of interest, and

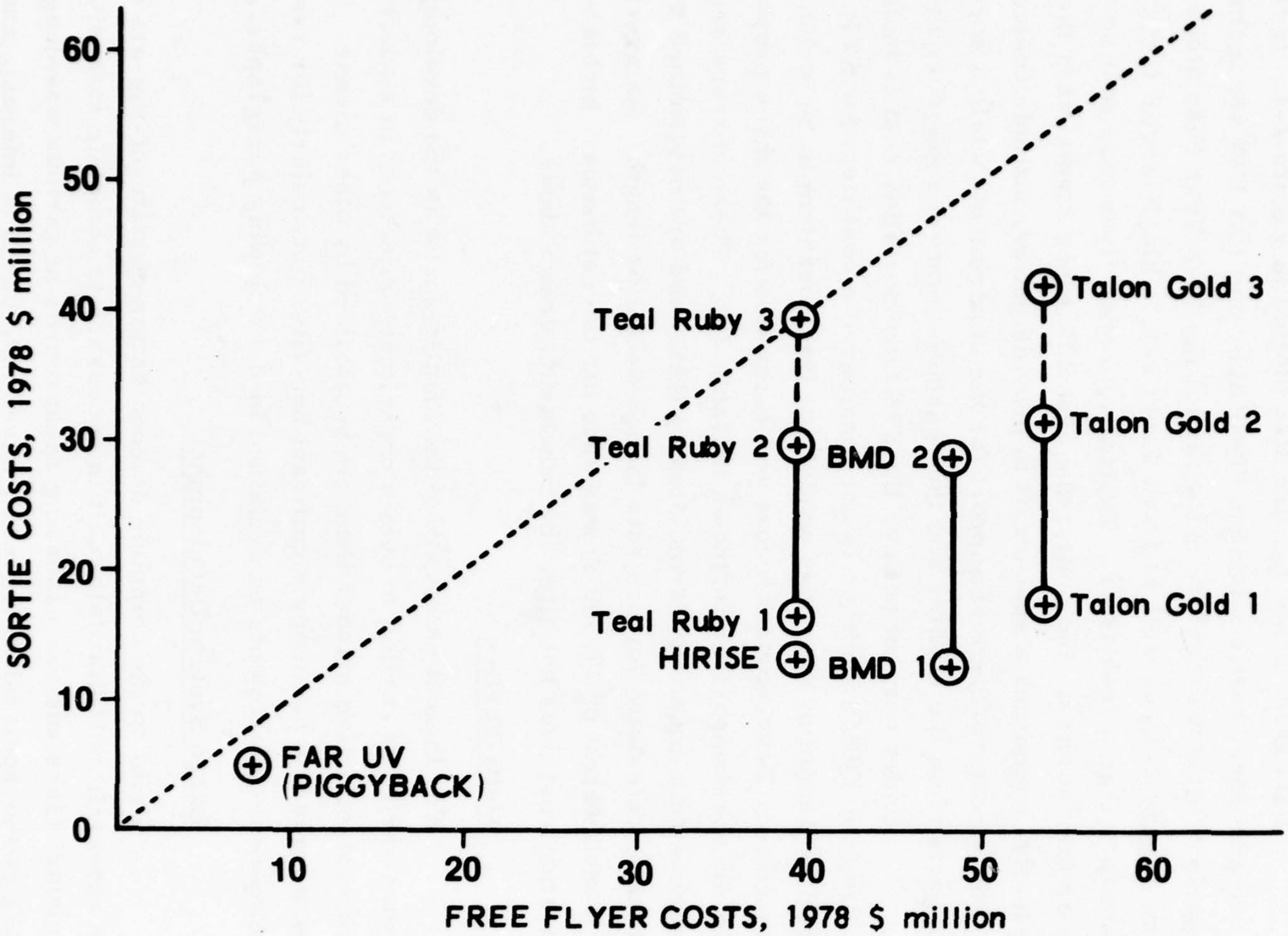


Figure 2-1. Free-Flyer vs. Sortie Costs

Table 2-2. Sortie vs. Free-Flyer Cost Comparisons Including STS Transportation Charges

Cost Elements	Missions/Estimates in 1978 $ Million								
	HIRISE		BMD			Talon Gold			
	Free-Flyer	Sortie	Free-Flyer	Sortie No. 1	Sortie No. 2	Free-Flyer	Sortie No. 1	Sortie No. 2	Sortie No. 3
Subtotals (from Table 2-1)	40.4	12.3	48.2	14.1	14.9	52.6	17.7	13.2	9.2
STS Transportation	3.6	3.4	3.9	3.3	3.7	6.5	4.1	3.5	3.5
TOTALS	44.0	15.7	52.1	17.4	18.6	59.1	21.8	16.7	12.7

defining operating parameters for later space demonstrations. In addition, measurement of responses to natural or induced environments that can only be crudely simulated on earth are often necessary prior to specification of optimum lens sizes, filters, bandwidths, etc. Such tasks are also well suited to multi-sorties.

Multi-sortie missions for this class of experiments will generally start by manned laboratory level tests performed on brassboard systems or other developmental hardware. Following sorties will test second generation hardware with basic concepts proven by original sorties or dependent on previous sortie-gathered data. This step-by-step approach to space R&D will enable earlier space exposure to new concepts, reduce risks inherent with long development programs, aid in development management, and consequently result in lower overall mission costs.

A detailed example of this concept has been evaluated and is presented on the following pages for a larger space system demonstration. The step-by-step development approach to achieving a final operational system was used by some Air Force programs in the past. As this was prior to the advent of the Shuttle, a free-flying satellite launched by an expendable launch vehicle had to be used at each step. Consequently, it was costly and time consuming. The Shuttle makes it possible to use sorties for step-by-step development and as a result cost and time are reduced.

2.1.2.2 Scientific Data Gathering

A second use of multi-sortie missions is for the class of experiments designed to obtain data over large spatial or temporal areas, such as mapping missions. While free-flying vehicles have some advantages for this mission class, multi-sortie flights also possess great advantages. Multi-sorties are superior where various orbital inclinations are needed, instrument modifications or additions are desired between data gathering periods, low altitude data must be collected over long periods, or only special seasonal effects are measured.

2.1.3 Questions for Mission Planning

In determining if a specific mission can best be accomplished by the single- or multi-sortie approach, a number of questions need be considered. These include:

a. Does the mission require data collection over large spatial or temporal areas?

b. Are instrument modifications or additions required between data gathering periods?

c. Are the additional risks of a long duration free-flyer justified?

d. Are there many unknowns factored into the basic instrument concept, the results achievable, or the responses expected?

e. Does the instrument require state-of-the-art design?

f. Is an extended time interval required for data evaluation between successive experiments?

g. Are orbit inclination changes or a low earth orbit required to obtain adequate results?

h. Are there advantages in having the instruments retrieved?

i. Have trades been made considering integration, launch, retrieval and hardware development costs?

j. Can man be utilized in obtaining mission objectives?

After an answer to these questions has been determined, an assessment of performance achievable by the multi-sortie concept can be compared to other approaches, such as expended or retrieved free-flyers.

2.1.4 Example of a Large Space System Demonstration

The following example demonstrates the considerations that must be traded when determining how to space test a state-of-the-art space sensor system. The advantages and disadvantages of the free-flyer and step-by-step, multi-sortie approaches to final space demonstration are evaluated. Mission objectives are defined and possible test flight scenarios are proposed.

2.1.4.1 Mission Objectives

For this discussion, let us assume that the objectives of the program are to demonstrate capabilities of acquiring space targets at long range, of tracking and pointing at a target with high precision, and of maintaining the target within the field of view with extreme stability. Evaluation of the acquisition, tracking, and pointing system will be done using an optical system large enough to achieve the resolution necessary to test pointing and stability and to demonstrate the ability to develop a large telescope. As part of the demonstration, the system must work with target vehicles that are passive and active and with a wide range of earth and space background conditions.

Acquisition of the target vehicle is the first requirement of the system and probably the most difficult, at least for passive targets. To acquire the target, a very accurate scanning mode must be used to search and identify.

Tracking of the target after acquisition is also difficult since the range may be very large and also the angular rate of change may be large. Variations in the background intensity that the target passes over may result in a low signal-to-noise ratio and make tracking very difficult, particularly for automatic devices which depend on the value of this parameter. For small, low contrast targets and noisy backgrounds, tracking will be very difficult for the passive cases.

2.1.4.2 Implementation

Development and testing of such a system can be performed by using an unmanned, remotely operated, and fully automated free-flying satellite or by using the Shuttle as a manned laboratory. With the first method, the experiment would be provided a free-flying platform with stabilization, controls, power, communications, and data handling services developed to support the telescope. Here active targets could be attached to the Orbiter and flown as multi-flight sorties. In the latter case, the experiment

would be mounted on a pointing system with services provided within (or possibly through) the Orbiter. In this case, one or more target vehicles would likely be deployed from the Orbiter to assist in active target operations where aircraft could not be used. Each of these methods needs to be evaluated carefully to determine advantages and limitations, as well as costs and time to develop the hardware and demonstrate the feasibility of the concept.

2.1.4.2.1 Free-Flyer Scenario

To obtain a reasonable degree of confidence in mission objectives, a preliminary design phase would be followed by buildup of a brassboard system. This brassboard would contain all new or advanced state-of-the-art portions of the experiment and would be put through extensive ground test simulating experiment performance and flight conditions, within practical limits. Results of these tests would dictate system design. Where accurate simulations were not possible or flight conditions are unknown, a degree of flexibility might be built into the flight hardware so that on-orbit alternatives could be chosen. One example of this might be to have command-selectable sensor scan patterns or techniques to increase confidence in target acquisition.

At the completion of brassboard ground tests, a flight qualified demonstration system would be fabricated. The flight system would draw heavily on brassboard test results and include various alternate modes of operation for those areas where ground test was indecisive or where more than one approach is to be demonstrated.

The demonstration system hardware would be designed with a high degree of redundancy to ensure successful operation for one year on orbit. The flight demonstration system would be constructed in parallel with a free-flying space vehicle which would provide an on-orbit injection system and platform, control, power, communications, and data handling services for the life of the mission. It is estimated that the complete space vehicle system would weigh approximately 7000 lb and be about 12 ft in length.

A small target vehicle would also be produced which could remain captive in the Orbiter bay during the various mission test sorties or could be deployed and remain on orbit.

Some of the more difficult flight demonstration problems would include identification of targets, automatic tracking with small signal-to-noise ratios, and telescope resolving power. Acquisition of targets might require an alternate approach using accurate ephemeris of the space vehicle and of the test targets. This could safeguard against inadequate preprogrammed target signatures or program update capabilities causing acquisition system failure. Tracking of targets with changing aspects and incidence of illumination likewise might require an alternate backup approach.

Resolving power of the telescope might be diffraction limited and, if so, images would be characterized by diffraction patterns rather than classical geometrical figures. Thus the demonstration system will require the ability to select a wide variety of target ranges. This could require a sequential series of tests with different targets that might have to be launched from the Shuttle.

2.1.4.2.2 Sortie Scenario with Manned Laboratory

Interactive operations in developing and testing the sensor system will involve more than the primary functions of acquisition, tracking, and pointing because the performance of the prototype flight system will be used in developing a large operational space system. Astronaut utility in this program will be demonstrated if the program can be realized with less cost, less risk, or less time than the unmanned approach.

The Orbiter would be used initially as an experimental laboratory to quickly gain experience and help resolve technical uncertainties inherent in advancing the state of the art. The crew is an integral part of this early brassboard test flight. Testing with the brassboard aboard the Orbiter would enable the use of actual environments while allowing

adjustments or changes to be made until high confidence in selected approaches was obtained. Tasks performed by the crew would be complete operation of the brassboard experiment, taking of data, analysis of data, and implementation of circuit changes. They would also perform calibrations, make equipment adjustments, and maintain contact with ground support personnel.

The next phase of the mission will make use of the manned Orbiter as the flight vehicle with an engineering model sensor system mounted on a cradle in the bay. The primary requirements of acquiring the target, tracking it during flight, and pointing could be done with the assistance of a payload specialist in the flight crew. All the equipment necessary to operate and test the system, including computational, control and display hardware/ software would be located on the Orbiter and controlled by the payload specialist. As a result, ground support could potentially be limited to technical consultation of the payload contractor with the payload specialist and with launch activities associated with target vehicles used in testing the system.

Dependency on a single approach to a scanning system for the sensor can be alleviated initially by using the astronaut. Human ability for pattern recognition and detection of moving objects against a noisy background could greatly enhance development testing and eliminate requirements for extensive communications of data to the ground and command and control information to the flight system. This could reduce development of support systems that might interfere with timely performance of the tests.

The assistance of a crew member in tracking for these flights will eliminate difficulties expected due to the signal-to-noise ratio because the eye functions very well in a noisy environment and a human observer can easily follow a point on a larger object which may be rotating. Further, details of the target vehicles may not be fully resolved by the telescope and diffraction patterns may also contribute to the apparent form of the object. While difficult for an automated tracker, the visual perception of a trained observer can accommodate these observations and function effectively.

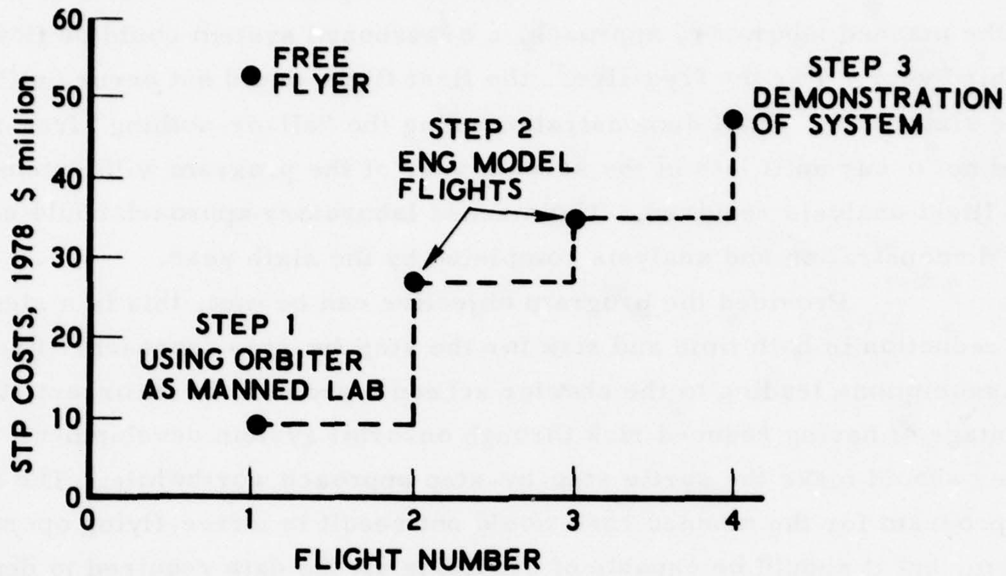
Evaluation of the image while pointing will certainly be required to interpret changes in focus, observations, and image brightness in the target as it is tracked. These are functions which experienced observers can perform readily and accurately since they are based on vision, knowledge, intellect, and physical dexterity (and are difficult to incorporate into a machine or transmit to the ground for real-time examination).

An additional consideration is that the image quality of the telescope and mechanical performance of the mount cannot be measured until the system is on orbit and stabilized. As a consequence, preprogrammed numerical control methods that must be employed in a free-flyer will have limited applications for automatic operations during initial test and evaluation of the system.

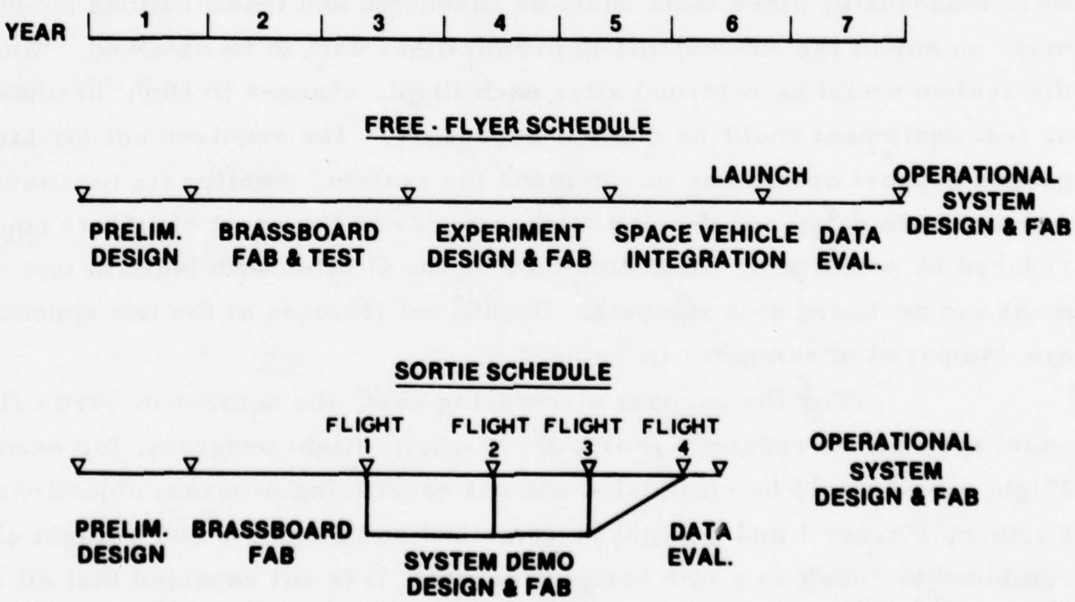
Crew-assisted tests should materially aid in rapid and relatively risk-free development of the required sensor system. As experience is gained and the basic system problems are solved independently of each other, the final demonstration system would be built up, flight by flight. Many benefits can be accrued including completing the mission objectives in less overall time and with more confidence than might be possible by other methods. Before completion of the system demonstration, major portions of the automated equipment would require flight test. This final test phase will be performed as a "hands off" demonstration but can still have the benefits of an astronaut in real-time observation and analysis, and potential repair and override of automated features.

2.1.4.3 Conclusions

Figure 2-2(a) demonstrates the estimated comparative STP costs for the free-flyer and sortie scenarios described above. STS transportation costs and developmental costs of sortie support equipment are not included. Comparison is not made here for the experiment costs but relatively similar costs are expected. While the final STP costs are not greatly different for either scenario, initial dollar risk is far less for the manned laboratory step-by-step approach.



(a) Estimated Cumulative STP Costs



(b) Possible Program Schedules

Figure 2-2.

In Figure 2-2(b) a comparison of possible schedules is made. For the manned laboratory approach, a brassboard system could be flown in the third year. For the free-flyer, the first flight would not occur until late in the sixth year. Final demonstration using the "all-or-nothing" free-flyer would not occur until late in the seventh year of the program with extensive post-flight analysis required. The manned laboratory approach could see final demonstration and analysis completed by the sixth year.

Provided the program objective can be met, this is a significant reduction in both time and risk for the step-by-step approach. Even if the assumptions leading to the shorter schedule prove to be incorrect, the advantage of having reduced risk through on-orbit system development testing should make the sortie step-by-step approach worthwhile. The flight test program for the manned case would not result in a free-flying operational system, but it should be capable of providing all the data required to demonstrate the concept. Performance data on the system would be recorded on board and analyzed to determine its completeness and quality. If the data were inadequate, other tests could be conducted and modifications could be made on any of the subsystems to permit other data to be obtained. Since the system would be returned after each flight, changes in flight hardware or test equipment could be made if necessary. The requirement for large ground support operations to command the system, monitor its functions, communicate data, and develop work-arounds in the event of failure could be reduced by performing these functions on the Orbiter with built-in test equipment and on-board data analysis. Significant features of the two approaches are compared in summary in Table 2-3.

For the purpose of reducing cost, the number of sortie flights could possibly be reduced. For a three-sortie flight program, for example, Flight 3 or 4 might be eliminated without sacrificing program objectives. Further, Flights 1 and 2 might be combined and Flights 3 and 4 might also be combined to result in a two-sortie program. It is not expected that all sortie

Table 2-3. Effectiveness Comparison for Free-Flyer vs. Multi-Sortie Development Approach

Features	Free-Flyer Approach	Manned Laboratory Approach
Mission Simulation Validity	Valid	Probably Valid
Flight Durations	1 Year	7 Days Each
Operational Flexibility	Low	High
Experiment Risk	High	Low
Mission Schedule	Flight Begins 6th Year	First Flight in 3rd Year Demo Complete in 6th Year
Hardware Development	Difficult	Guided by Early Flight Experience
Cost	High	Potentially Lower than Free-Flyer

missions require four flights, but the four-flight sortie program is used here for illustrative purposes.

2.1.5 Tethered Systems

Tethering is a method of removing an experiment or a complete satellite from the Orbiter bay environment while still maintaining orbital control from the Shuttle. Tethering might be desirable because of adverse electromagnetic interferences, Shuttle bay contamination, field-of-view obstructions, unsafe operations, Orbiter wake effects, or a need to obtain greater or lesser orbital altitude. In general, tethering implies a separation distance from the Orbiter not generally achieved by use of deployed booms. However, in some cases the remote manipulator system or other booms will function to remotely place a captive experiment or system for extended periods to meet some of the tethered system objectives. The ultraviolet sensors of the LASSII mission may be examples of this use.

There are no presently available tethered systems for use by STP. There also appears to be no major STP need for such a system in the near-term future. However, NASA has seen a variety of applications for a tethered system, particularly for satellite systems to be deployed into lower orbits, that can be achieved by the Orbiter. For this reason, NASA has initiated conceptual studies for a tethered system. The resulting Tethered Satellite System (TSS) consists of an extendable boom and tether used in a gravity gradient mode to deploy satellites of up to 400 lb mass into lower or higher earth orbit at ranges up to 50 nmi (Ref. 2-3). At mission completion, the tether is retracted until the satellite is recaptured by the extended boom. The satellite/boom assembly is then restowed in the Orbiter bay for return to earth. Present NASA plans call for preliminary designs that will continue into a development phase and possibly an operational capability by 1983.

2.2 MANNED OPERATIONS

2.2.1 Astronaut Utilization

The unique capabilities of humans are the result of their intellect and knowledge combined with physical attributes of mobility, dexterity, and visual perception. These faculties, which can be only approximated by machines, can provide outstanding performance and versatility when used properly in the design of space systems. The critical factor in manned space flight operations is in using astronauts in systems in which unique human skills can be meaningfully applied. Full advantage can then be taken of their presence to reduce time and costs in developing and flying space systems.

For the STP, manned operations may be of great value since the programs are for research, development, or testing requiring new methods, technology, and innovations. These are the types of programs in which the presence of an astronaut should be most effective and should provide the greatest benefits in time and cost reductions. Examples of how astronauts can contribute are given in the following.

2.2.1.1 Interactive Operation

Astronaut use in operating equipment can permit instruments to be flown in the early laboratory or prototype stage, reducing the time to develop automated vehicles and payloads. An operator familiar with the equipment can efficiently evaluate its performance, determine operating limits, conduct critical tests under actual space environment operating conditions, and determine modifications to be made. The hands-on use by a skilled person can eliminate the need for complex and costly remote automatic operational equipment and consequently increase reliability. Astronaut use also results in greater flexibility to on-orbit operation plans, reduced communication requirements, and minimal ground support.

Inherent human flexibility allows greater on-orbit prioritization (filter changing, aperture adjustment, etc.) of experiments in response to real-time situations. Security can be maintained without employment of encrypting equipment through the use of on-board recording and return of tapes or films with the orbiter. Tape recorder cartridges or film canisters can be changed in the cabin or remotely. On-board management can also be utilized in meeting multiexperiment payload objectives, particularly when recalibrations or realignments may be required. When a series of flights are used for a single experiment, man provides a quicker and less expensive reprogramming capability than the usual software or hardware techniques.

Experiments interested in "targets of opportunity" or non-cooperative targets are particularly suited to on-board control. Plans for a number of experiments include using an astronaut to "edit" operations and make real-time decisions. A payload specialist will select sensor target sites, determine priority of targets, and selectively control data taking, as well as remotely point sensors and otherwise manually control the experiments.

2.2.1.2 Visual Observations

The crew can make extensive visual observations using telescopes, spectrometers, cathode-ray tubes, wavelength transformation devices, and the unaided eye. These can be done rapidly and continuously in a real-time mode and reduced simultaneously. No analysis need be done or data recorded or transmitted until required conditions are present. Extensive experience with ground-based observatories and with Skylab has demonstrated that in collaboration with optical instruments the eye has greater capability than other sensors in color and texture resolution and in identifying patterns in a noisy field. These abilities greatly reduce the communications and computation problems for systems that search, acquire, track, and examine other objects.

2.2.1.3 Data Analysis

Real-time analysis of data can be done by the crew and assessment made to determine quality and adequacy. This will enable new observations to be made immediately if results are incomplete, indecisive, or flawed. Based on evaluation of data, new tests may be developed and conducted during the mission, and equipment may be changed to accomplish the revised objectives. This eliminates transmission of large volumes of data to the ground for analysis and the subsequent transmission of results to the payload.

2.2.1.4 Initialization

For systems that are to be deployed, start-up, checkout, and calibration can be done with high reliability by the crew. This can guarantee that all systems are functioning properly prior to release. Malfunctions can be corrected and failures repaired or the spacecraft can be returned for re-work. Tests of a satellite in free-flying escort mode by the Shuttle can also be conducted while the vehicle is observed by the crew.

2.2.1.5 Assembly, Deployment, and Restowage

For large systems that must be assembled or deployed on orbit, manned operations may be the only reliable and cost effective method available. The crew can supervise deploying and restowing of a large payload and can control the sequence of operations to prevent malfunction or damage. They can assist in the event of problems such as jammed parts or incorrect sequencing and replace parts that are broken or will not function. Such payloads must not represent a hazard to the crew and they or their constituent parts must be large enough so that a space-suited astronaut can operate them.

These requirements and others tend to cause payloads to be large, complex, and expensive. In order to reduce cost, large payloads requiring assembly and deployment should be built so that they can be used by several different sponsors with differing objectives. These payloads

could be configured and procured by an agency whose interest is broader than the single experiment, such as DARPA or NASA. Such an approach would require the payload to be recoverable, refurbishable, and capable of alteration either on earth or in space, depending on the mode of operation chosen.

2.2.1.6 Release and Retrieval

Manned operations can be of great value to the release and retrieval of satellites that are tethered mechanically or optically, are intended for free flight, or need to be recovered for repair, refurbishment, or reuse. The crew will also participate in chemical releases and other experiment-related releases. Satellites that will require an orbit change or launch from the Shuttle will necessitate release, alignment, and firing. These operations can be done most effectively and safely by a crew member. For rendezvous, docking, and retrieval of satellites, use of the crew may greatly simplify requirements for equipment and communications.

2.2.1.7 Refurbishment

A factor of orbital operations that will increase in importance is the refurbishment of space systems to improve performance, revise purpose, or reuse parts. With the use of modular construction, changes can be made quickly with a limited crew and support facilities. On-orbit moving of large and heavy parts can be done efficiently, and alignment and attachment can be designed for extravehicular activity (EVA). Instead of transporting large instruments from earth to space and back, we may eventually leave the instruments in space and replace critical items such as focal planes, photoelectric converters, filter sections, expendables, or complete modularized subsystems. A mission specialist can set up garaged equipment and initialize data acquisition.

2.2.1.8 Maintenance and Repair

Use of prototype equipment and elimination of redundancy required for automatic operations on board the Shuttle will result in

increased requirement for on-orbit repair and maintenance. Life of free-flying satellites can also be improved by implementing a plan of preventive maintenance. This can be easily done with manned operations using modular constructing techniques, hand tools, replacement parts, and built-in test equipment. Computerized built-in test equipment similar to the NASA developed Built-In Test Equipment (BITE) system for the Shuttle would allow "go/no-go" testing, self-check, and failure isolation. Associated displays could enable the crew to select alternate programs to pinpoint sources of trouble and alter operational signal flows as temporary work-arounds. Such on-board computers and crew-assisted failure analysis can diagnose failures and specify repairs that can be done by the crew during the mission. On-site analysis could prove valuable to equipment redesign of multi-mission hardware where real-time observation of the malfunction is possible. Examples of this might include anomalous operation of gimbals or booms in the zero-g environment.

2.2.2 STP Applications

These unique astronaut capabilities and STP experiments that will make use of these capabilities are recapped in Table 2-4. The functions marked with "X" are considered by STP as required to perform the experiments; those marked with "0" are considered as desired or as backup operations.

2.2.3 Limitations of Manned Space Operations

The limitations of humans in the space environment are also factors in assessing the utility of manned operations. Although the problems are not serious impediments, they must be given due consideration in developing a flight program. These factors include the following.

2.2.3.1 Biological Factors

Human biological characteristics are an important consideration in astronaut mission effectiveness. Psychological factors that do not

Table 2-4. Potential Payload Specialist Utilization for STP Sortie Experiments

Experiments	Capabilities							
	Interactive Operations	Visual Observations	Data Analysis	Initialization	Assembly, Development, Restowage	Release, Retrieval	Refurbishment	Maintenance, Repair
Approved								
Artificially Dist. Ionosphere			0	0		X		
HIRAD			0					
CI Spectrometer								
Awaiting Approval								
Talon Gold	X	X	X	X		X		
HIRISE	X	0	0	X				
BMD Target Meas.	X	X	0	X				
ROMS/P	X		0	0	X			
LASSII	X	0		0	X	X	0	
SEEP								
Far UV	X	X	0	X			0	0
SEPS	0		0		X			
CIRRIS (EIRE Renamed)	X	0	0	0				
SAGE	0	0	0					
HUP	0	0	0					
New								
PDMM			0	0	X			
Optical Countermeasures	0		0	0	X			
TABS	X	X	0	X		X		

X Astronaut Required
0 Astronaut Desired

affect machines may disrupt the crew's ability to operate effectively. They are subject to illness and accidents that can interrupt or stop their activities. Periodically they must stop working to sleep; in addition, eating, waste elimination, and hygiene requirements disrupt their functions.

2.2.3.2 Fatigue

Humans have limited ability to work effectively for extended periods without fatigue, so periodic interruptions are required. Fatigue also leads to excessive errors both in judgement and in work. Human attention span in routine and repetitive jobs is also limited, and thus they do not function well when used for such work.

2.2.3.3 Strength

Human strength when compared with a machine is low and is limited to a few operations for maximum application. The power level is also low -- less than one horsepower for continuous performance.

2.2.3.4 Response Range and Accuracy

Although the dynamic range of the human eye to light levels is extremely high, the wavelength range is very limited. The accuracy of the eye, as of the other senses, to measure physical quantities such as radiation, temperature, mass, and time is very low. Humans can make only qualitative judgements.

2.2.3.5 Environments

The most significant limitations of astronauts result from the environment they require. They can survive only in a limited temperature range and with a closely controlled atmosphere free of certain gases. Acceleration and shocks must be limited to low values. The naturally occurring charged particle radiation environment is also an important problem for astronauts. The charged particle radiation is composed of two principal components, the geomagnetically trapped electrons and protons

that are nearly constant and solar protons that vary greatly. Available data show that at altitudes below about 400 nmi the integrated dose is less than 1 rad per day for .007 lb/in^2 shielding. In addition to the trapped particle environment, solar flare particle emission must be considered. For orbit inclination below about 60 deg and altitudes less than about 6000 nmi, the solar flare proton environment is considerably less severe than the trapped radiation and can be ignored. However, for higher inclinations the exposure to solar flares becomes important. In a low altitude (150 nmi) polar orbit the skin dose behind .04 lb/in^2 of aluminum would have exceeded the 30-day allowable dose of 75 rads in three flares recorded in recent years. This does not consider possible evasive actions that could have been taken such as optimum spacecraft orientation over the poles or additional body shielding. Such action would significantly reduce the doses indicated.

2.2.4 Manned Operation vs Automation

Before a space system can be optimized for return of information or economy, basic considerations of crew usage must be evaluated. Should the experiment and support systems make exclusive use of manned operations with no automatic control; should highly automated hardware be used with astronauts only as backup; or should some combination of these techniques be employed? The answer to these questions can be obtained only after specific mission-peculiar requirements have been established.

Some space missions will require only simple repetitive operations. Some will require more complex operations such as inspection of targets of opportunity. Still other complex systems may require human dexterity and intelligence for such tasks as deployment of large space structures. For each individual case, the crew utility and the benefits they can bring to experimental results must be weighed against their limitations and those imposed upon the mission objectives. The most important considerations are outlined in the following and these will have to be evaluated for each new mission.

2.2.4.1 <u>Advantage of Unmanned Automatic Systems</u>

Remote automatic systems have dominated space operations to date. As a result these systems have become very reliable for particular applications such as communications and navigation which require simple and repetitive tasks to be performed. Others with complex command, control, and organization capabilities have been fully operated from a ground control center with excellent performance. Some of the advantages of remote automated operations are:

2.2.4.1.1 <u>Programmed Operations</u>

On-board computers can be programmed to perform a number of operations rapidly and continuously without supervision. Complex logic can be included in their operation and simple learning can be made a part of the program.

2.2.4.1.2 <u>Environment</u>

Requirements for the environment of an unmanned system are less stringent than for manned. Although the temperature range must be restricted, the systems can operate in a vacuum and withstand much higher acceleration and shocks. The charged particle radiation is less of a problem for instruments, and no biological restrictions exist. Mechanical systems can remain on orbit for years and be abandoned or retrieved when they stop operating. A wide range of high (or low) orbits can be used that cannot be reached by the Shuttle. Long-duration flights can be made and the selection of orbits is not restricted because of charged particle radiation either in the trapped regions or from flares. Recovery of the payloads is not required after the mission is completed.

2.2.4.2 <u>Limitations of Unmanned Automatic Systems</u>

Remotely operated automatic systems have several disadvantages that limit their usefulness to special purpose operations. These are:

2.2.4.2.1 Economics

The Shuttle era is here and manned operations are already available. Many functions that can be performed adequately by machine may be accomplished more economically by astronauts since they, and their support systems, will be aboard the Orbiter. Several of these types of functions are pointing of sensors, reducing data, and calibrating instruments.

2.2.4.2.2 Adaptability

One of the major limitations of unmanned systems is the impracticality of modifying or refurbishing them for different purposes after the original objectives have been attained. Large special purpose systems that perform many specific tasks automatically may be more expensive to reuse than the alternative development costs for new hardware.

2.2.4.2.3 Reliability and Repair

Since all systems eventually fail (usually in an unpredicted way), unmanned operations are vulnerable. With these systems, only redundancy or modified operations can effect a repair and then usually only by reducing the capability of the system or impairing performance. Replacement of failed parts or release of jammed mechanisms is usually not possible.

2.2.4.2.4 Command and Control

For low-earth-orbit satellites with moderate requirements for communications, command, and control, the present ground control centers are adequate. However, for the STP operation during the Shuttle era, when more payloads and large complex systems like Talon Gold will be flown, these problems may be acute. For remote operation of a system requiring closed-loop servo control, transit time delays between ground control and the spacecraft will limit the rates of control to very low frequencies. Data rates necessary to monitor and command these larger systems will also be very high and frequently inaccessible from existing communication centers.

2.2.5 Optimum Astronaut Use

One most valuable human attribute is the ability to react to unexpected events such as the occurrence of targets of opportunity and equipment malfunctions or failures. For these events, human intellect and knowledge combined with visual perception and physical dexterity are of the greatest utility in flight operations and can result in optimum mission effectiveness. The recognition of unique targets, operation of instruments, quick-look data analysis, and the diagnosis and repair of malfunctions or failures can be accomplished best by manned operations. Further, interactive ground- and space-based operations achieve maximum benefit from an observer on orbit. To accomplish these functions with automatic and remotely controlled equipment would require very complex special purpose systems. As demonstrated by the Skylab program, flight operations with scientific and advanced technology experiments require interactive monitoring, control, and repair in order to achieve mission objectives.

It is expected that the high level of performance achieved in the Skylab program will be realized in the Shuttle operations with experience in effective use of the crew and development of adequate interactive control equipment. Design of payloads to utilize manned operations fully and training of a payload specialist to operate flight instruments effectively will be important considerations in reaching optimum astronaut use. At present NASA is planning to train the Orbiter flight crew consisting of the commander, pilot, and mission specialist. However, training for a payload specialist will be only for life support and emergency routines. As a result, training of the payload specialist and development of interactive control systems for the experiments is the responsibility of the user. Consequently, the STP Five Year Plan includes development of the manned aerospace support equipment (MASE) and the associated training equipments. These required capabilities are discussed further in the Section on Common Support Equipment.

2.3 COMMON SUPPORT EQUIPMENT (CSE)

2.3.1 Needs for Common Support Equipment

Factors influencing the space test of experiments in the sortie flight mode are:

a. Exploitation of the quick-reaction potential of the Shuttle,

b. Realization of a "Buffer" between Shuttle and Experiments,

c. Implementation of security, and

d. Utilization of astronaut capabilities

2.3.1.1 Exploitation of the Quick-Reaction Potential of the Shuttle

Quick reaction to the needs of the DoD experiment community is necessary to speed the infusion of new technology into present and future military operational systems by providing more frequent opportunities to test in space. This can be accomplished by minimizing experiment flight lead time, shortening Orbiter integration time, and making use of existing equipment and the astronaut potentials.

Experiment lead time, or the time from experiment inception to space flight, can be shortened by providing standardized interfaces to the experimenter prior to procurement of hardware. This approach enables the experimenter to procure hardware early in experiment development with the assurance that his experiment will be compatible with supporting services and with other experiments in the payload. The reflight of systems hardware in sorties not only allows the development of a proven and well understood set of requirements but is essential for economic reasons. The repeated use of the Orbiter and support systems will also enable a fuller understanding of the flight environment, which will consequently allow the elimination of excessive design margins that have historically been required for reliability.

Present NASA plans incorporate such thinking. The Orbiter is fitted with standard services for use by the payload including structural support,

telemetry, command, electrical power, thermal control, experiment pointing, and astronaut working space. These services are planned to be made available on a pro rata basis for mixed payload cargos; i. e., each cargo segment will have access to a portion of these services based on the percentage of Orbiter bay used. While, in general, this appears to be an adequate solution to proportioning services, some required services are not available to the experiment and must be individually provided. These include analog-to-digital conversion, multiplexing, bulk data storage, and astronaut interface equipment for payload control and operation.

2.3.1.2 Realization of a "Buffer" Between Shuttle and Experiments

Actual intermixing or sharing of experiment services introduces some potential difficulties for their use. Operational time-lines must be generated at an early stage in mission development to ensure peak load handling compatibility. Also, there is the question of security for DoD experiments (particularly when carried on NASA flights).

Additional questions also arise as to the feasibility and compatibility of the wide range of experiments that may form a mixed cargo for any given flight. For these reasons NASA and the DoD have prepared tentative integration time-lines providing for feasibility studies and configuration reviews (Ref. 2-4). The total time-line cycle (feasibility studies to launch) can take in the order of three years if each mixed or shared mission is treated as a totally unique set of payloads requiring complete support services, integration, and verification. This is precisely what might be expected if, for example, each experiment was simply supplied to NASA for integration on a mixed payload mission. The same thing could also occur on DoD flights if a method is not implemented to reduce the overall integration tasks. The key considerations concerning complexity of mixed payload integration are the interactions between the payload segments making up the total cargo. These

interactions can be categorized as structural, thermal, electrical, loads/dynamics, contamination, electromagnetic interference (EMI), and mass properties.

Reduction of the structural, thermal, and electrical interactions can best be obtained by the elimination of the need for these interfaces. Structural interfaces are reduced (although they may never be fully eliminated) by avoiding the use of structural elements that are common to separate cargo segments, such as the pallet train described in Appendix A. That is, all the STP experiments should be "buffered," or mounted, and operated from an independent (STP dedicated) structure not connected to other payloads within the Orbiter bay. Likewise this structure, or cradle, should provide Orbiter-independent thermal control. Electrical interactions can also be reduced and made independent from other cargo bay payloads if such services are self contained for the STP experiments. Interface iterations resulting from the sharing of command, telemetry, and power would be eliminated, thus reducing costs, schedules, and changes dictated by each modification that is made in the total cargo mix.

Loads and dynamic interactions can be eliminated by careful design and use of mechanical mounting structures plus the control of experiment design requirements and test specifications. Qualification of the STP common support equipment (CSE) must include worst-case "envelop" requirements in order to provide a "class cargo", or one that will eliminate future requalification tests or STS integration verification analysis.

Physical integration of a "class cargo" is compared with Spacelab integration in Figure 2-3. The figure shows the four-level NASA approach to physical STS integration ending with a final Orbiter integrated test on the launch pad. This sequence is preceded by lengthly feasibility and design analyses to ensure compatibility between all parts of the complex mix of experiments on each Spacelab pallet and between cargo segments on the several pallets or in the Spacelab module. A fully independent and dedicated STP-developed set of common support equipment will avoid the largest

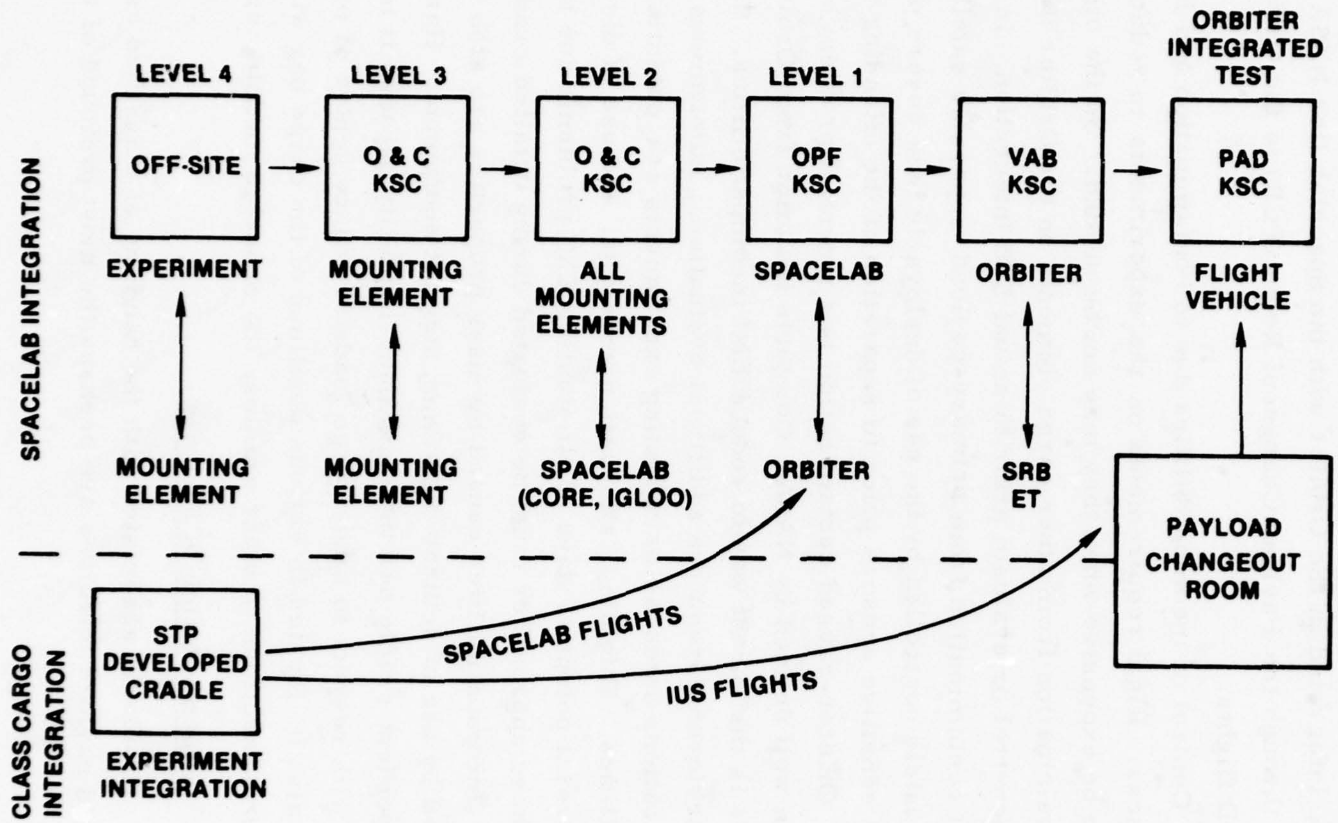


Figure 2-3. Comparison of Spacelab Integration and Class Cargo Integration

portion of the analyses due to elimination of the major interfaces. As shown in the figure, the STP cradle-experiment integrated equipment can then immediately be integrated in the Orbiter with the Spacelab (for NASA Spacelab flights) or through the Payload Changeout Room (PCR) to the Orbiter at the pad for DoD flights.

Control of incompatibilities due to contamination and EMI are difficult to assess. Rigid requirements on the experiments to reduce contamination can be expensive when they may not be needed. On the other hand, excessive contamination from other cargo elements on the Orbiter itself may be difficult to control or evaluate prior to actual STS integration. In some cases external contamination from primary-payload separable satellites might be adequately controlled by the use of deployable lens covers or similar appendages on sensitive sensors prior to separation of the offending source.

Orbiter-caused contamination is a potential problem but has not as yet been well defined by NASA. Complete isolation from Orbiter electrical services is the surest way to reduce EMI incompatibilities. The area of RF interference requires additional evaluation. Autonomous cradles with communications antennas or radiating experiments are potential sources of incompatibilities. Shielding, attenuation networks, and use of directional arrays are several potential ways of eliminating EMI problems due to radiation. All of these approaches must be evaluated during detailed cradle design.

Incompatibilities caused by mass properties are also most easily resolved by use of dedicated common support equipment. Here, the shortest independent cradle has the maximum flexibility because it is most easily moved with respect to other cargo loads to reduce center of mass problems. It can also be located in various positions of the cargo bay without regard to interconnections to other cradles, the Spacelab module, or igloo.

2.3.1.3 Implementation of Security

Problems associated with the handling of classified experiments on mixed payload missions are perhaps the most profound of all

potential incompatibilities. Security may include the needs of secure integration and test facilities, personnel clearance, need-to-know access, electrical isolation to avoid unauthorized data dissemination, and encryption of clear text data. Maintenance of security for personnel-related activities (integration, test, access) are best handled by conducting the majority of the integration effort at facilities remote from the rest of the mission cargo. Performance of all experiment integration and all but the minimum of final verification tests can only be completed in this manner if the support services are independent from the Orbiter itself. Complete electrical isolation to avoid unauthorized emission of classified data is also most easily accomplished when using totally independent systems. Secure coding requirements dictate the provision for encryption and decryption hardware as an integral part of the total support system.

Even with these precautions, mixed NASA mission flights for classified experiments will probably be impractical due to ultimate Shuttle access to uncleared personnel. While most of the security considerations are manageable when STP experiments are flown as a part of DoD missions, the primary user may exclude the experimenters from the Orbiter integration site for security reasons. Here again, the most efficient solution is for the STP to make use of fully independent common support equipment, thus limiting need for access to the Orbiter.

2.3.1.4 Astronaut Utilization

The potential uses of astronauts and the many advantages to experiment operation, control, and maintenance have been described. If these potentials are to be realized, astronauts must be able to interact with the cradle-mounted experiments. There must be versatile and highly adaptive hardware and software systems by which operations can be controlled, data edited or analyzed, and results interpreted. The crew must also be able to maintain support systems, analyze failures, and implement work-arounds. Specific functions that could be performed by such a system are shown in Table 2-5.

Table 2-5. Functions Performed by the MASE

Automation of Routine Tasks	
o	Turn "on" and "off" or make mode changes in cyclic equipment
o	Output system status on routine basis including command history
o	Time correlate events, commands, and human input functions
o	Take telemetry sampling
o	Monitor tape recorder operations
o	Distribute commands
o	Make routine self-checks/warning
o	Calculate ephemeris
Support Systems Self-Check	
o	Monitor temperatures of critical equipment
o	Check system voltage and battery charge state
o	Monitor redundancy and hardware element selection
o	Calibrate in-flight telemetry
o	Monitor status of operating systems, e.g., tape recorder mode, gimbal servo bandwidth, etc.
o	Signal output levels limit check
Experiment Data Processing and Reduction	
o	Count events for display as a function of time, amplitude, or wavelength
o	Output maximums, minimums, or average of inputs as a function of time or other variable
o	Delete data outside of programmed limits
o	Compress data within prescribed limits
Data Display	
o	Make CRT presentations in form of plots, graphs, tabulations, limits, statistical averages, etc.
o	Provide warning light for exceeded limits
o	Provide "go/no-go" displays
o	Make hard copy of displays
o	Provide printer outputs
Failure Analysis Routines	
o	Cause alarm when self-checks do not agree with planned outputs
o	Initiate redundancy switching to isolate faults
o	Inject signals and measure responses in amplitude, frequency, or pulse widths
o	Accept simple routines input by a crew member

These functions are not unusual or difficult to implement. In fact they are all routinely performed in the ground control station, data reduction center, or laboratory today. The NASA-developed Built-In Test Equipment (BITE) for the Shuttle will perform automated self-checks and might provide a basis to the STP for this function. Automated "control and data bus" systems such as the TT&C hardware to be flown on the STP P78-1 mission provide adaptive data sampling and command distribution. Here software algorithms provide highly reliable, nonambiguous implementations for system control functions and can be incorporated to provide standard interfaces with mission flexibility. Techniques and methods for data processing of research and development experiments are extensively used by SAMTEC for past and present STP flights and can be emulated in flight hardware.

By development of a flight hardware/software system, standardization of interfaces can be achieved without loss of flexibility or adaptability; yet individual experimenter needs can be met with minimum change. The system will provide the means for efficiently utilizing human capabilities in orbit by reducing routine and simple tasks and by providing the tools for effective experiment control, data analysis, and failure repair. In fact, the only way to make use of the crew to the full extent of their abilities is to provide them with the means to receive inputs from the experiments and the ability to implement decisions with relative freedom from ground control.

2.3.2 CSE Description

In the preceding paragraphs the concept of a class cargo consisting of a fully autonomous set of common support equipment was developed. This CSE consists of all Orbiter bay experiment support equipment required as well as that equipment required in the Orbiter aft flight deck to enable the astronaut capabilities to be utilized. The equipment required to perform these services are listed in Table 2-6 and the basic interrelationships are diagramed in Figure 2-4. As shown in the table, a large portion of the required hardware can be drawn from existing designs with a minimum of modification or new design required.

Table 2-6. Common Support Equipment

Cradle Equipment

- o Structure*
- o Electronic Support Subsystems

  Command Decoder*
  Encrypter*
  Command Distributor*
  Telemetry Encoder*
  Transmitter*
  Batteries*
  Power Regulator and Distributor
  Tape Recorder*
- o Pointing Gimbal*
- o Antennas*
- o Thermal Control*

  Radiator*
- o Cables

Manned Aerospace Support Equipment (MASE)

- o Controls

  Keyboard*
  Joy Stick*
  Switches*
  Decrypter*
- o Visual Display

  Cathode Ray Tube*
  Formatter*
  Status Lights*
- o Computer

  Logic*
  Memory*
  Software
- o Cables

*Available as existing spacecraft hardware or developed for use in the Orbiter

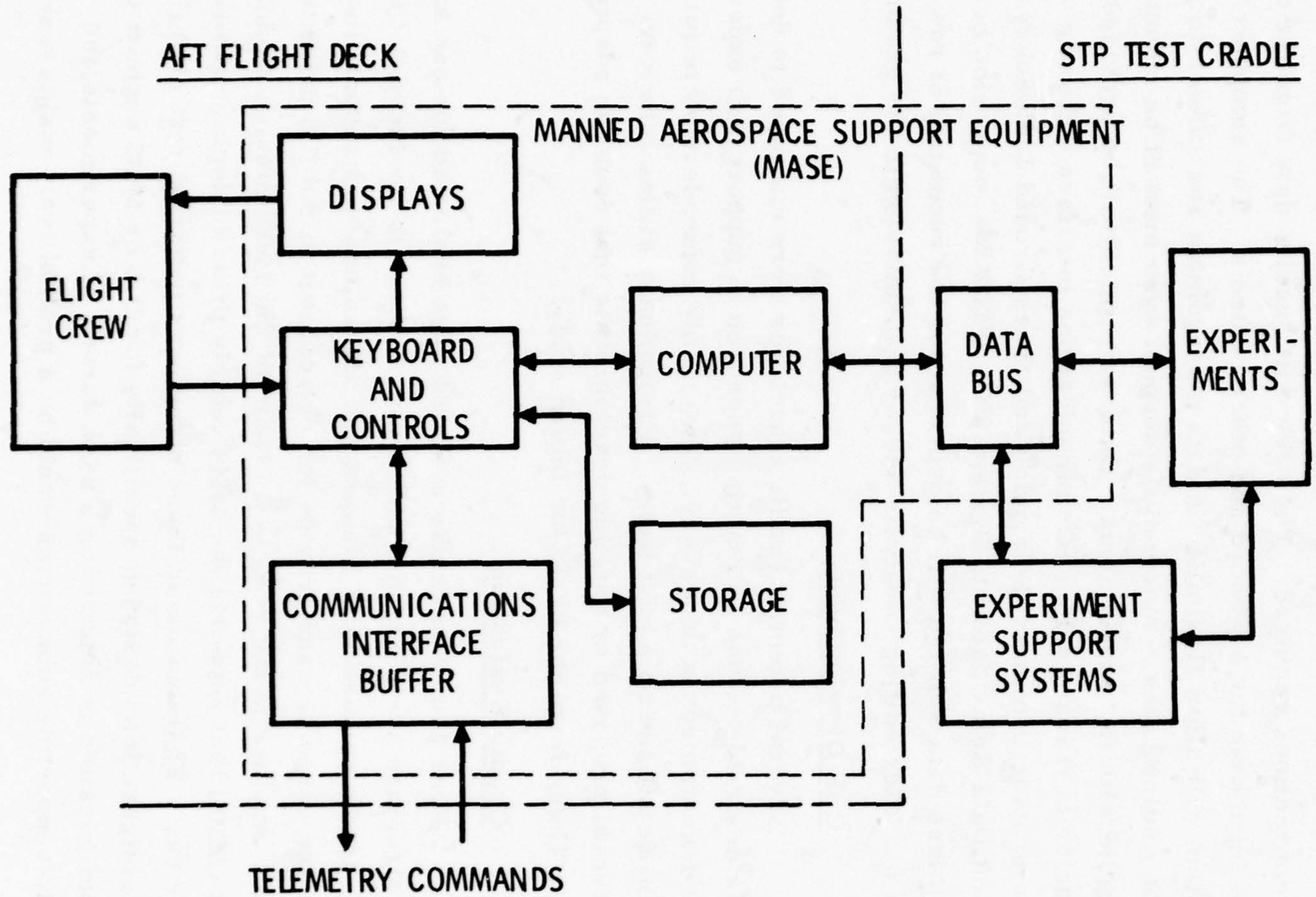


Figure 2-4. Block Diagram of Common Support Equipment (Autonomous)

Figure 2-4 indicates the location of the flight equipment and the basic interconnections required. The crew will receive data from the displays and provide inputs via the keyboard and other controls. The computer/data bus subsystem will allow flexibility in data management and automatic performance of routine tasks. Autonomous support systems will be mounted on the STP cradle with the experiments. Data encryption will be provided (if required) prior to transmission. Communications interface buffering will be available to provide command decryption and Space Ground Link Subsystem/ Tracking and Data Relay Satellite System (SGLS/TDRSS) conversion as required. Mass data storage will be provided for the recording of raw experiments data for later editing, analysis and/or transmission to the ground.

2.3.3 CSE Development

Several potential cradle structures were examined to determine if it is desirable to use an existing approach to support DoD experiments or if a new development is necessary. Two viable contenders were further compared in detail and on a cost basis. Preliminary evaluations were also made of several proposed or existing developments that could be adapted to MASE use. These form the basis for future study.

2.3.3.1 Cradle Evaluation

Four proposed cradle systems were evaluated for use as the cargo bay structure portion of the CSE. One of these is the Inertial Upper Stage (IUS) cradle consisting of forward and aft frames that support the IUS vehicles in the cargo bay and provide for detachment of the IUS prior to deployment. Another is the retention cradle of the Multimission Modular Spacecraft (MMS) that supports the MMS vehicle prior to deployment from the Orbiter bay. Examination of these structures indicated that modification from the configurations designed specifically for IUS or MMS support to a general configuration of supporting a wide variety of experiments and experiment-supporting subsystems would be a prohibitively major task.

The NASA/ESA 3-m pallet and the Standard Test Rack (STR) were also evaluated. The 3-m pallet is designed primarily for use with the NASA Spacelab or igloo and is described in more detail in Appendix A. The STR is a version of a similar but shorter (4-ft) cradle designed to be highly flexible and modular in construction. The STR resulted from a study contract under the joint auspices of the SAMSO LV and STP offices (Ref 2-5).

Since both the 3-m pallet and the STR were found to be highly competitive candidates for future CSE development, a further more detailed comparative evaluation was performed. This evaluation was directed to the determination of the best overall cradle configuration for use by the STP, both from an economic point of view as well as from flexibility to meet future STP needs. This study made a cost comparison between autonomous and non-autonomous versions of the two cradles. The nonautonomous STR provides the 4-ft STR cradle furnished only with experiment pointing and Orbiter interface equipment. The DoD use of an autonomous 3-m pallet means that the pallet structure would be purchased from NASA and fitted with Orbiter-independent services. The nonautonomous pallet consists of a purchased 3-m pallet supplied with experiment pointing hardware and interface equipment so as to make use of all Orbiter services. Total payload (experiment plus support equipment) carrying capabilities are compared for the two basic cradles in Table 2-7.

Cost breakdown for the four options studied are shown in Tables 2-8 and 2-9. Estimates for the autonomous STR were derived from Refs. 2-5 and 2-6. Additional information for estimating the nonautonomous STR and the 3-m pallets was obtained from Refs. 2-2 and 2-7. Comparative results of the total cost evaluation are summarized in Table 2-10. Costs are considered for flight hardware, support equipment, ground operations (both experiment and STS integration), NASA STS transportation, and other charges (spares, documentation, crew training, post-flight operations, and refurbishment). Table 2-10 is compiled to demonstrate basic cost factors and differentials between the alternative approaches. Many of the reference sources

Table 2-7. Payload Size and Weight Capability (STR vs Pallet)

Basic Cradles	Length, ft	Load Capacity, lb	Available Volume, ft^3	Working Volume, ft^3	Structure Weight, lb	Exposed Surface, ft^2	Maximum Circular Diameter Envelopes, ft
STR	4	8000	580	530	1500	115	3.0 5.80 without Bridge
Pallet	10	6600	1150	1025	1400	227	6.25

Table 2-8. Summary of STR Cradle Costs[a]

Cost Item	Estimates in 1978 $ Million	
	Autonomous	Nonautonomous
Design, Development & Fabrication		
Structure		
Power, Thermal, Telemetry, Pointing		-
Orbiter Interface Equipment	-	
System Engineering & Test		
Ground Support Equipment		
Software		
Spares		
Total for Single System		

Table 2-9. Summary of 3-m Pallet Costs[a]

Cost Item	Estimates in 1978 $ Million	
	Autonomous	Nonautonomous
Structure Purchase		
Design, Development & Fabrication		
Power, Thermal, Telemetry, Pointing		-
Orbiter Interface Equipment & Experiment Support Structures	-	
System Engineering & Test		
Ground Support Equipment		
Software		
Spares		
Total for Single System		

[a]As noted on the inside front cover, cost figures have been deleted.

Table 2-10. Summary of Cradle Comparative Costs[a]

Cost Item	Estimates in 1978 $ Million			
	STR		3-m Pallet	
	Autonomous	Non-Autonomous	Autonomous	Non-Autonomous
Nonrecurring Costs				
Flight Hardware Support		b		b
Equipment Amortized over 20 Flights				
Ground Operations Cost ($ Million/Flt)				
Experiment - Cradle Integration				
Cradle - STS Integration				
STS Transportation				
Other				
Total Cost/Sortie (Based on 2 Flts/Yr for 10 Yr in $ Million)				
Including STS Transportation Costs				
Excluding STS Transportation Costs				

[a] As noted on the inside front cover, cost figures have been deleted.

[b] Includes costs for experiment pointing

for costing information are in pre-release or even conceptual phases of development and, therefore, are subject to some uncertainty. Transportation charges are included for completeness and are based on the NASA reimbursement guide. These charges will vary depending upon the assumed mission weights; for this table an "average" mission weight of 4500 lb for experiments and cradle systems was used. Additionally, it was assumed that the total Orbiter cargo weight would be limited to 37,300 lb on the average.

The largest cost differences seen in Table 2-10 are due to the flight hardware charges. For the autonomous cases these costs indicate the initial investment for autonomous support systems and must be balanced against the advantages discussed previously for CSE that do not depend upon the Orbiter interfaces. As seen from the table, there is no major cost advantage of one approach over the others when development nonrecurring costs are amortized over 20 flights. Another cost differential for STS integration is expected to occur between the autonomous and nonautonomous systems. It is expected that integration charges due to the large number of interfaces of the nonautonomous cradle would be higher as shown. The most significant cost differential between the STR and the 3-m pallet occurs when STS transportation charges are considered. Typically, the STR will have a lower charge for STP missions since it is weight critical while the 3-m pallet is length critical. This results from the 4-ft cradle length of the STR as opposed to the 10-ft length of the NASA pallet.

Another factor considered in this evaluation of potential STP dedicated cradles was the effects of flight opportunities due to cradle length. Table 2-11 summarizes the latest available information for both NASA and

Table 2-11. STP Flight Opportunities Per Year (1980-1985)

Cradle	Flight Opportunities		
	NASA	DoD	Total
STR	10.5	4.5	15.0
3-m Pallet	6.8	4.5	11.0

DoD flight availability. This tabulation considered weight and space capabilities of the Orbiter bay but did not evaluate potential center-of-mass problems, availability of the aft flight deck, or primary payload security restrictions on DoD missions. Both cradle types appear to offer adequate flight opportunities to ensure at least two STP sorties per year.

The STR does exhibit a technical advantage when flexibility to a wide variety of experiments is considered. The STR was developed to be completely modular in construction, both for mechanical support of experiments and pointing gimbals as well as for additions or changes to electrical support equipment on a mission basis. The proposed construction of the STR should reduce both internal and external EMI problems and simplify security needs.

2.3.3.2 MASE Evaluation

There is no available system that can perform the necessary astronaut interfaces as defined for the MASE although the need for adequate payload specialist support has been recognized previously by NASA (Ref. 2-8). There are, however, several proposed systems that will perform portions of the required tasks and can be drawn on for design and hardware.

The Air Force-developed Communications Interface Unit (CIU) will provide a secure command uplink and a secure data downlink from the Orbiter bay (via the aft flight deck) either directly from the AFSCF remote tracking stations (RTS) or through the STDN (Space Tracking and Data Network) or TDRS systems. This system is being developed to interface with the IUS for pre- and post-deployment checkout. The CIU will be very limited in display capability (status lights) and in astronaut-initiated commands ($\approx$50) and will not contain a computer (Ref. 2-9).

The NASA is developing a Built-In Test Equipment (BITE) system for limited "go/no-go" Orbiter in-flight testing. It is expected that

this system will not be available for use by experimenters. The Orbiter has a certain limited capability of other hardware available for potential use by experimenters (Ref. 2-10). However, the majority of this hardware (computer and display) consists of Orbiter backup spares and could require sharing both with other cargo users and the Orbiter flight crew.

Study effort now being planned by the STP office will further evaluate these equipment options and initiate plans for the development of a flexible modular MASE system that can best meet existing and future DoD experimenter needs for sortie flights.

A cost estimate for this fully instrumented MASE is summarized in Table 2-12. Additionally, for comparison, this table contains an estimate of a MASE system that is limited to CRT display and a keyboard for astronaut input. This limited system could be used for highly automated experiments with a limited need for astronaut support.

Table 2-12. Summary of MASE Costs[a]

Cost Item	Estimates in 1978 $ Million	
	Full Capability	Limited Capability
Design Development & Fabrication		
Display		
Keyboard	-	
Formatter		-
Computer		
Joy Stick		
Additional Display & Control		
Systems Engineering & Test		
Ground Support Equipment		
Software		-
Total for a Single System		

[a]As noted on the inside front cover, cost figures have been deleted.

2.3.4 CSE Procurement

The many advantages of flexible, modular, and autonomous CSE have been described. It has been shown that there are no major cost advantages for either the 3-m pallet or the STR. Likewise, amortized costs of autonomous CSE have been shown to be similar to costs for equipment utilizing the available Orbiter experiment services. The next step leading to procurement of autonomous CSE is to develop an acquisition plan that will provide the necessary experiment services when needed with the least risk.

2.3.4.1 Multiphased Approach

When embarking on any extensive project, particularly one that must be flexible and meet the needs of a number of different users, it is wise to proceed slowly and gain experience with the minimum of risk. Just as was proposed for the demonstration of large experimental systems, development of the CSE can use the step-by-step approach. In this way, the fully autonomous CSE can be developed one step at a time and, therefore, incur the least cost and schedule risk. This step-by-step or multiphased procurement approach can be accomplished while supporting a mission schedule as assumed in Fig. 4-1 (Section 4).

The first sortie mission could be BMD. This experiment does not require a pointing system since pointing of the sensor is an integral part of the experiment. Additionally, the manned aerospace support equipment needed for this sortie mission is limited since an astronaut is required only to monitor instrumentation status, maintain communications, control test sequences, and perform corrective tasks in case of malfunctions. A control panel which will contain most of the necessary hardware to perform these tasks will be provided by the experimenter. This allows the acquisition of CSE by the multiphased approach. The first phase would obtain a cradle structure for experiment support along with the minimum electronics to interface with Orbiter electrical services. This phase would also acquire limited control and display hardware to augment experimenter-provided items. For

the BMD mission, then, the experiment would be mounted on an STP-dedicated cradle but would share available Orbiter power, command, and telemetry. Data would be transmitted through the orbiter to the ground station via the Tracking and Data Relay Satellite.

The second procurement phase would begin with CSE to support the next sortie mission, such as HIRISE. Here, a pointing system would be required as well as other cradle hardware such as secure command and telemetry links. The pointer could be procured from one of the available sources (see Appendix A). The communications interface would require encryption/decryption equipment and may make extensive use of CIU described earlier. Additional interaction between the HIRISE experiment and the astronaut would also require additional upgrading of the MASE. A computer and a limited amount of software routines would be added to allow editing, evaluation of sensor data, and control of pointing. High resolution display would be required for pattern recognition.

A third sortie mission, such as Talon Gold, could require an additional upgrading phase of both the cradle and MASE portions of the CSE. Since requirements of this mission are not firm, it is not yet clear exactly how complete the upgrade must be. This might include an increase in control, display, computation, and software capabilities.

Shortly after (or during) the third sortie mission it is expected the complete CSE will have been upgraded to its final autonomous state. The progression of upgrade cycles building upon initial structural support and Orbiter services will allow a well-planned experiment support system to be developed. This approach will ensure the minimum of risk since the system capabilities will grow as more experience is obtained in actual working environments under actual experiment support conditions. Future CSE acquisitions will then be limited to the potential increase in software for special needs and the maintenance and refurbishment required between sorties.

This step-by-step procurement approach is compatible with the sortie schedules as shown in the Recommendations and Impacts Section

of this document (Figure 4-1 in Section 4). The planned additional MASE evaluation study and preparation of a competitive procurement package must be initiated in the near future so that a contractor can be selected and placed on contract by the end of FY 1979. This first procurement phase will enable delivery of the first two nonautonomous cradles and the first limited MASE in late FY 1981 preparatory to the integration of the first mission (BMD).

Two cradles are required for this mission to house the sensor and target assemblies (Ref. 2-1). A third cradle and second MASE must be produced and delivered during the second procurement phase for integration of HIRISE in early FY 1983 (since the second BMD flight occurs in the last half of that year). As mentioned above, this CSE will provide more services than those required for the BMD mission. Under the proposed schedule, both BMD and HIRISE CSE would be available prior to Talon Gold needs and could, therefore, be refurbished and upgraded during the third procurement phase for this mission. However, to allow adequate upgrade time and to avoid schedule conflicts if the BMD mission should be delayed as well as to provide increased schedule flexibility for future sorties, an additional fourth cradle is proposed. This system could be delivered by the end of FY 1983 and would be an upgraded version for Talon Gold. Two of the other CSE sets would also be upgraded following the development of this fourth unit. This three-phase procurement schedule for the CSE is summarized in Figure 2-5.

Table 2-13 summarizes the phased-procurement costs to produce a proposed complement of four cradles to support the planned sortie missions. The first three cradles would be fully upgraded during the upgrade cycle while it is planned to leave the fourth cradle (at least for the present budget period) in the nonautonomous configuration. Cost estimates were derived by using cost figures proposed earlier in this section for the autonomous and nonautonomous STR. Nonrecurring and recurring costs for the upgrade of cradle No. 1 were taken from Table 2-8. Upgrading costs were assumed to be the difference between the costs estimated for the autonomous

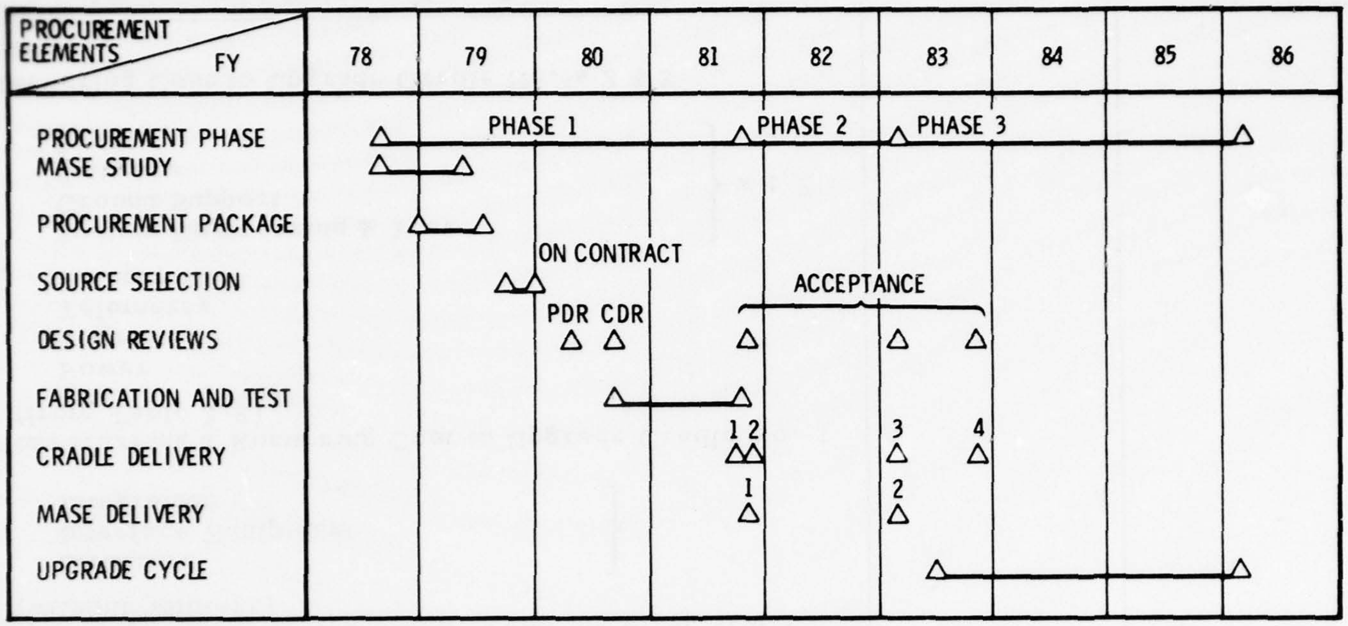


Figure 2-5. CSE Procurement Schedule

Table 2-13. Summary of STP Cradle Phased-Procurement Costs[a]

Cost Item	Estimates in 1978 $ Million	
	Initial Procurement	Upgraded Procurement
Nonrecurring & Recurring Costs for Cradle No. 1 (from Table 2-8)		-
Recurring Costs for Additional Cradle No's. 2, 3, & 4 (without pointers)		
Structure Interface Equipment Integration		-
Nonrecurring & Recurring Cost to Upgrade Cradle No. 1 (from Table 2-8)		
Power Thermal Telemetry Pointer	-	
System Engineering & Test Ground Support Software Spares × 1.2	-	
Recurring Cost to Upgrade Cradle No.'s 2 & 3	-	
Total Procurement Cost for Four Cradles and One Pointer (Cradle No. 4 not Upgraded)		

[a]As noted on the inside front cover, cost figures have been deleted.

and nonautonomous version of the cradle (assuming 80 percent efficiency). The costs for upgrade of the remaining cradles, No. 2 and No. 3, were derived from hardware, integration, and other recurring cost estimates. Only one pointer system is costed and it would support the HIRISE mission.

MASE costs were similarly estimated for a phased-procurement of two systems and are summarized in Table 2-14. As for the case of the cradle estimates, the costs to upgrade the first MASE were assumed equal to the difference between estimates for a single full capacity and a limited capacity system (again assuming an 80 percent efficiency). The upgrade of the second MASE likewise is an estimate for only the recurring costs required.

The total costs to develop the CSE by the planned phase-procurement approach are spread over an eight-year period, ending with the maximum planned capabilities in FY 1986. This cost is shown in Table 2-15 in "then year" dollars assuming a 6 percent per year inflation factor.

2.3.5 Crew Training

One of the most critical factors in implementing manned operations is training flight crew members to operate the experiments effectively. The principal responsibility for experiment operations is assigned to the payload specialist, if one is assigned to the mission. The payload specialist should be someone who is intimately familiar with the details of operation and the idiosyncrasies of the primary experiment and, therefore, should be provided by the experimenter. This specialist will be fully trained in operation of the experiments through the on-board interface control equipment and will receive additional training for orbital flight emergencies and for life support and hygiene. For less complex experiments on deployed payloads, the mission specialist crew member can perform flight tasks and will require training in experiment operations. NASA will be responsible for training crew members for emergency operations and life support functions, and the STP will be responsible for experiment operations training.

Table 2-14. Summary of MASE Phased-Procurement Costs[a]

Cost Item	Estimates in 1978 $ Million	
	Initial Procurement	Upgraded Procurement
Nonrecurring & Recurring Costs for MASE No. 1 (from Table 2-12)		--
Recurring Costs for Additional MASE No. 2		--
Nonrecurring & Recurring Costs to Upgrade MASE No. 1 (from Table 2-12)		
Design, Development & Fabrication Systems Engineering & Test Ground Support Equipment Software × 1.2	--	
Recurring Cost to Upgrade MASE No. 2	--	
Total Cost for Two Upgraded MASE		

[a] As noted on the inside front cover, cost figures have been deleted.

Table 2-15. Cash Flow for CSE Phased-Procurement[a]

Cost Item	Est. Cost/Fiscal Year in Then Year $ Million							
	79	80	81	82	83	84	85	86
Cradle								
3 Initial Units with 1 Pointer						-	-	-
Upgrade 3 Units and Produce 1 More Nonautonomous Unit	-	-	-	-				
Total Cradle Costs								
MASE								
2 Initial Units						-	-	-
Upgrade of 2 Units	-	-	-	-				
Total MASE Costs								
Total CSE Costs								

[a]As noted on the inside front cover, cost figures have been deleted.

In order to utilize the crew members effectively in operating the experiments, it will be essential to develop an intensive and well rehearsed training program using facilities that simulate those in the Orbiter. Experiment support during flight will primarily be provided through the MASE located on the aft flight deck. This equipment will provide the means to control the instruments and to analyze flight data and display results for evaluation. The crew will be trained to make effective use of the MASE, to maintain the equipment, and to make repairs or develop work-arounds if required. The engineering model MASE is planned to be used for this purpose. The payload specialist will also be trained to operate all of the experiments on the STP mission. This instruction will be the responsibility of the appropriate experimenters.

The training facilities, which may be located at an STP contractor's system integration site, will also be used to develop and test the computer control program used with the MASE to operate experiments. During flight it can be used by the ground-based experimenters to support the payload specialist, to develop new programs which may be needed, and to devise work-arounds for malfunctions or failures. Ground support can also be provided to the payload specialist to assist in the operation of unfamiliar secondary experiments. This method was very effective in obtaining optimum results from the Skylab/Apollo telescope program.

3. FREE FLYER MISSIONS

3.1 FEATURES

A free-flyer is a self-sufficient satellite launched by the Shuttle and separated from it once on orbit. It is usually transferred to a specialized orbit by an orbit transfer stage and stays on orbit for an extended period of time, typically one year. In general, the transfer stage provides a plane change and an altitude change from the Shuttle parking orbit. One free-flyer mission in the Five Year Plan is the MSP/Mini-HALO satellite which is transferred from the Shuttle by an Inertial Upper Stage (IUS) to a geosynchronous orbit. Unlike the sortie mission which draws support of power, attitude control, telemetry, and thermal/structure from the Orbiter or the STP common support equipment, the MSP/Mini-HALO experiment is provided with these supports on board the satellite.

The STP launches free-flying satellites in two modes: primary and secondary (or piggyback). In the primary mode, STP procures the spacecraft, integrates the experiments with the spacecraft to form the self-sufficient satellite, integrates the satellite with the orbit transfer stage and a support cradle, and then integrates the entire package (called a "payload" by NASA terminology) with the Shuttle. The MSP/Mini-HALO mission is a primary mission. In the secondary (or piggyback) mode, STP either procures a self-sufficient satellite (called a subsatellite), which is integrated with another program's satellite and launched together into orbit, or integrates experiments and minimal support subsystems with another program's satellite. The subsatellite leaves the host vehicle and is transferred to another orbit by a propulsive system. Good examples of the subsatellite mode are the three STP S-3 flights launched in 1974, 1975, and 1976. The Five Year Plan investigated the possibility of flying subsatellites on the IUS vehicle as described in the following. An example of integrating experiments with another program's satellite is the STP S80-1 mission, which flies four

experiments on the NASA Long Duration Exposure Facility (LDEF) which is described in Appendix A.

A free-flyer can be left on orbit for an indefinite period of time or recovered after one or two years of operation. The MSP/Mini-HALO satellite will not be recovered once on orbit since there is no economic way available today to retrieve a satellite from the geosynchronous orbit. Satellites in low earth orbits are amenable to recovery. There are three principle reasons for recovery; these are:

a. The experiment objectives are satisfied only when the experiment is brought back to earth for analysis and inspection. The samples and films in the S80-1 experiments to be flown on LDEF are in this category.

b. The space hardware has a value for reuse. The hardware may be a complete satellite, a subsystem, or a component which is costly to produce.

c. The space hardware is retrieved and recovered to prevent random reentry. The Dynamic Power System (AFAPL-601) is a good example. In this case, recovery is an alternative to inserting the experiment into a non-decaying orbit. But post-flight inspection of the wear and tear of the rotating machinery is an added advantage for recovery.

For experiments in the first category, there is no tradeoff between recovery and non-recovery since recovery is required. For experiments in the second and third categories, a cost tradeoff must be performed to show that cost benefits exist for recovery. (A preliminary figure of about $17 million was estimated for using the Teleoperator, proposed to NASA by the Martin Marietta Corporation, to recover a satellite from a low-earth orbit without a change of inclination being required.) The STP Five Year Plan does not contain a planned recovery operation, except for the LDEF whose recovery is executed by NASA.

A free-flyer depends on manned operations for deployment. The Orbiter crew will actively participate in deploying the Satellite/IUS

payload for the MSP/Mini-HALO mission as for all free-flyers. The crew is primarily concerned with releasing the payload in a safe manner and firing the IUS motor at a safe distance.

The STP is concerned with the status of the satellite and therefore will implement a procedure for status checkout prior to release, similar to the implementation for the Teal Ruby mission. The DoD STS Program Office is concerned with the status and control of the IUS which will be implemented through the planned Communication Interface Unit (CIU).

Deployment is one area in which all parties concerned will be in a "learn as we go" process until the procedures mature. Aside from the deployment procedures, one additional manned operation for MSP/Mini-HALO deserves consideration which is related to the sun-shade of the sensor optics. Due to its size (12 ft or longer), a trade exists between installing the sun-shade on the ground and installing it by a crew member on orbit. These options are being considered in the mission planning.

Free-flying missions do not have the severe orbit constraints of the Shuttle's altitude and inclination. The frequent requirement of low inclination, highly elliptical, or high altitude orbits makes free-flyers necessary. Use of the Orbit Maneuver System (OMS) kits and weight restrictions attendant to sun synchronous orbits also adds restrictions on opportunities offered by the Shuttle in the sortie mode. Experimenters utilizing free-flyers will benefit from ample flight opportunities due to the high traffic flow of the Shuttle to place experiments in a wide variety of orbital environments.

Because of long on-orbit duration, a free-flyer offers experiments a greater chance than a sortie to observe events that either occur infrequently or require a large amount of data for understanding. This is particularly suited for making measurements of the space environment to build a data base for modeling. It also offers seasonal coverage as often required by experiments, such as the Teal Ruby.

The problems of Shuttle contamination (gases, particulates), experiment incompatibilities (looking up vs. looking down, dirty vs. clean payloads, deployment vs. line-of-sight requirements, etc.), and hazardous situations (venting of noxious gases, generation of EMP, x-rays, very high voltages), illustrate situations where free-flyers, in general, have advantages. Special missions causing, or sensitive to, these circumstances are good candidates for free-flyers. The safety of an astronaut is not an issue on free-flyers, and viewing problems are greatly mitigated. (Up-looking and down-looking payloads are frequently accommodated on the same spacecraft without orientation changes.) Restowing an experiment is not necessary for safety considerations, eliminating the need for special mechanisms. In many circumstances, free-flyers place less limitations on the experiments than sorties.

3.2 PRIMARY FLIGHTS

The STP will follow existing policies of procuring spacecraft for primary flights, namely, using standard or existing spacecraft whenever feasible and building dedicated spacecraft only when required. A standard spacecraft is one that is designed to be a general purpose spacecraft for a variety of missions. An existing spacecraft is one that is designed for a specific mission and is still in active procurement. In either case, if the number of modifications to the existing design are sufficiently small for a given STP experiment complement, there is likely to be a cost saving relative to using a dedicated spacecraft.

As an example, STP considered the use of the Multimission Modular Spacecraft (MMS) for the MSP/Mini-HALO mission. The requirement imposed on STP that both sensors utilize the same spacecraft has resulted in a serious weight problem: the capability of the two-stage IUS for the required geosynchronous orbit is 5000 lb, and present determination of overall satellite weight only allows for a 15 percent weight growth. This is considered inadequate. If use of a standard spacecraft, such as the MMS (see Appendix A),

allows comparable or higher weight margins, its use would be advantageous. A preliminary determination of the required modifications to the baseline MMS for MSP/Mini-HALO are tabulated in Table 3-1:

Table 3-1. Required Modifications to Baseline MMS

Added Equipment	Weight Added to Baseline, lb
Tape recorders	75
Carrier 2-link	40
X-band link	116
Solar array and drive	210
Batteries and support	216
Hydrazine and support	324
Mini-HALO radiator and miscellaneous thermal	222
IUS adapter	200
Subtotal	1,400

When added to the baseline MMS weight of 1466 lb and experiment weight of 1770 lb, a total weight of 4636 lb is obtained. The dedicated spacecraft weight is 290 lb less (see Ref. 3-1). On the basis of this preliminary calculation, no weight advantage exists; however, continuing definition of experiment requirements will result in some likely spacecraft subsystem requirement modifications. Therefore, STP will continue to examine the implication of these to the use of the MMS for this application.

A cost comparison between using the MMS and a dedicated spacecraft was also made for the MSP/Mini-HALO mission. A breakdown of costs for this mission is provided in Table 3-2, for the MMS and a dedicated spacecraft. The estimated cost savings with the MMS is \$ [1] million (1978 dollars) or 8 percent, which is within the accuracy of the estimates.

[1]As noted on the inside front cover, cost figures have been deleted.

Table 3-2 Cost Comparison - MSP/Mini-HALO Mission MMS vs. Dedicated Spacecraft[a]

Cost Item	Estimates in 1978 $ Million	
	MMS	Dedicated
Basic MMS		
Spacecraft Subsystem Equipment		
TT&C Subsystem		
Electrical Power Subsystem		
Thermal Subsystem		
Attitude Control/Secondary Propulsion		
Structure and Deployment Mechanisms		
Design, Fabrication and Assembly		
Systems Engineering and Management		
FCRC and Contingency		
SINC Contract		
PIC Contract		
On-Orbit Support		
Total		

[a]As noted on the inside front cover, cost figures have been deleted.

These numbers will be revised as more detailed mission objectives are generated by the project office. It is expected that the attitude control, electrical power, and thermal subsystems will be most strongly impacted costwise by potential revisions and updates of payload requirements.

An existing spacecraft, as a candidate for the MSP/Mini-HALO mission in the event of weight growth beyond the 5000-lb IUS capability, is the Lockheed Satellite Control Section (SCS) described in Appendix A. This satellite has already been flown with a hydrazine stage which, when combined with the two-stage IUS, results in a payload capability to geosynchronous orbit of 6220 lb. There may be a possible weight advantage to the use of this spacecraft without the hydrazine stage. Further analysis of this is also underway in the MSP/Mini-HALO mission planning.

3.3 SECONDARY FLIGHTS

On a space available basis, STP launches experiments on other programs' satellites as a secondary or piggyback payload. In consonance with this objective, STP has flown over 4000 lb of experiment equipment in this mode. Looking back at the past problems with piggybacking on the Titan/Transtage family of vehicles, one is led to believe that many problems would have been attenuated if only the vehicle design had taken into account the piggyback potential. Stowage of a small satellite between the transtage and the primary payload would have been made more readily adaptable. This would have been a good location for many STP experiments such as PACSAT, E^2S^2, and SCATHA. Another suitable location would be the front end of the Titan second stage.

The success of STP flying a secondary payload on another SAMSO program stems from the fact that locations and pallets were designed into the host satellite and ready for use with no adverse impact on the primary payload. There is a need for a conscientious effort during the initial design of new vehicles (satellites and IUS) to make provisions which would facilitate the accommodation of secondary payloads.

In the case of the IUS, the following activities have taken place:

a. An initial discussion was held between STP and the Boeing Co. on 21 September 1977 for considering secondary space on the IUS. Twelve basic ideas were advanced to satisfy current needs of placing experiment equipment in 12-hr elliptic or geosynchronous orbits.

b. In December 1977, Boeing presented two more ideas for STP consideration. These are:

   1. Installing a subsatellite in the single stage IUS in place of the upper motor when the primary payload does not need the upper motor. See Figure 3-1.

   2. Using the IUS avionics bay as part of an STP spacecraft. This is the so-called Cost Optimized Service Module (COSMo) concept.

c. Lincoln Labs proposed in April 1978 superposing a DSCS III spacecraft bus between the IUS and an operational payload with the objective of flying advanced versions of the LES experiments.

d. During the course of the Five Year Plan study, discussions were held with the SAMSO STS Program office on using their existing study to explore the possibility of a torus-shaped satellite wrapping around the nozzle of the second stage motor. The Boeing Co. performed a conceptual study and the concept is illustrated in Figures 3-1 and 3-2. Mounting a small satellite externally on the interstage frame between the forward and aft support cradle is also a possibility.

The STP Five Year Plan includes studies to continue exploitation of these opportunities jointly with the SAMSO STS Program Office. In addition to the IUS, the Global Positioning System (GPS) block change for Shuttle flights and the Defense Meteorological Satellite Program (DMSP) block change and others offer opportunities to create secondary space for STP in their initial designs. The GPS and DMSP are of particular interest to STP because their special orbits can satisfy the needs of many DoD experiments.

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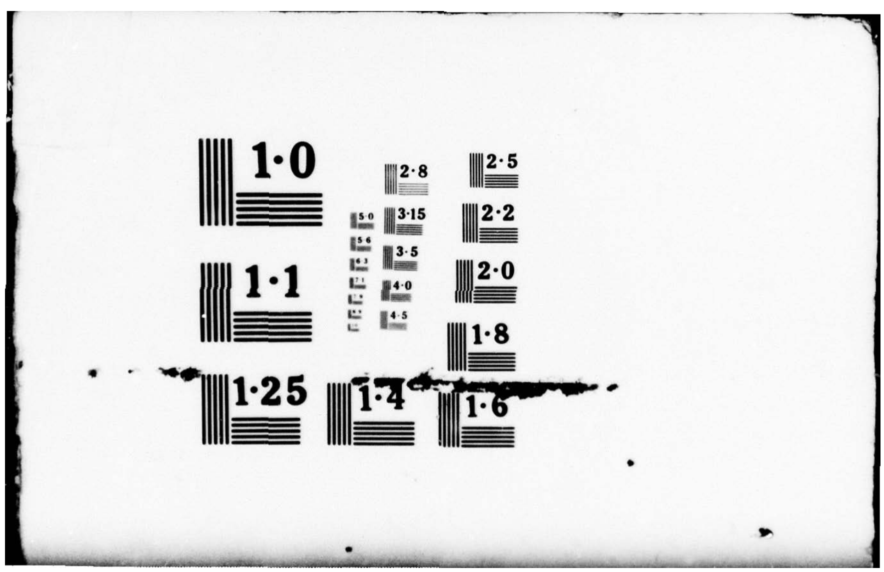
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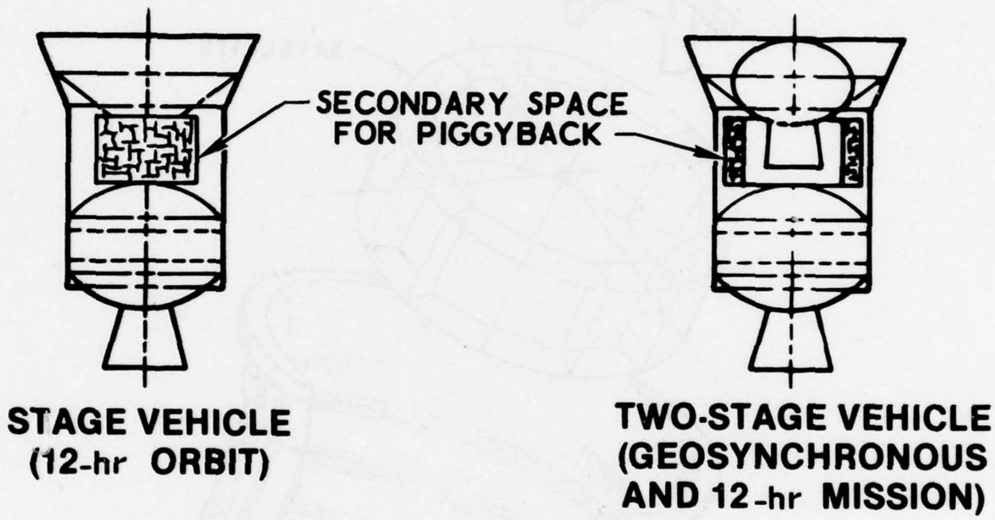


Figure 3-1. Piggyback Concepts

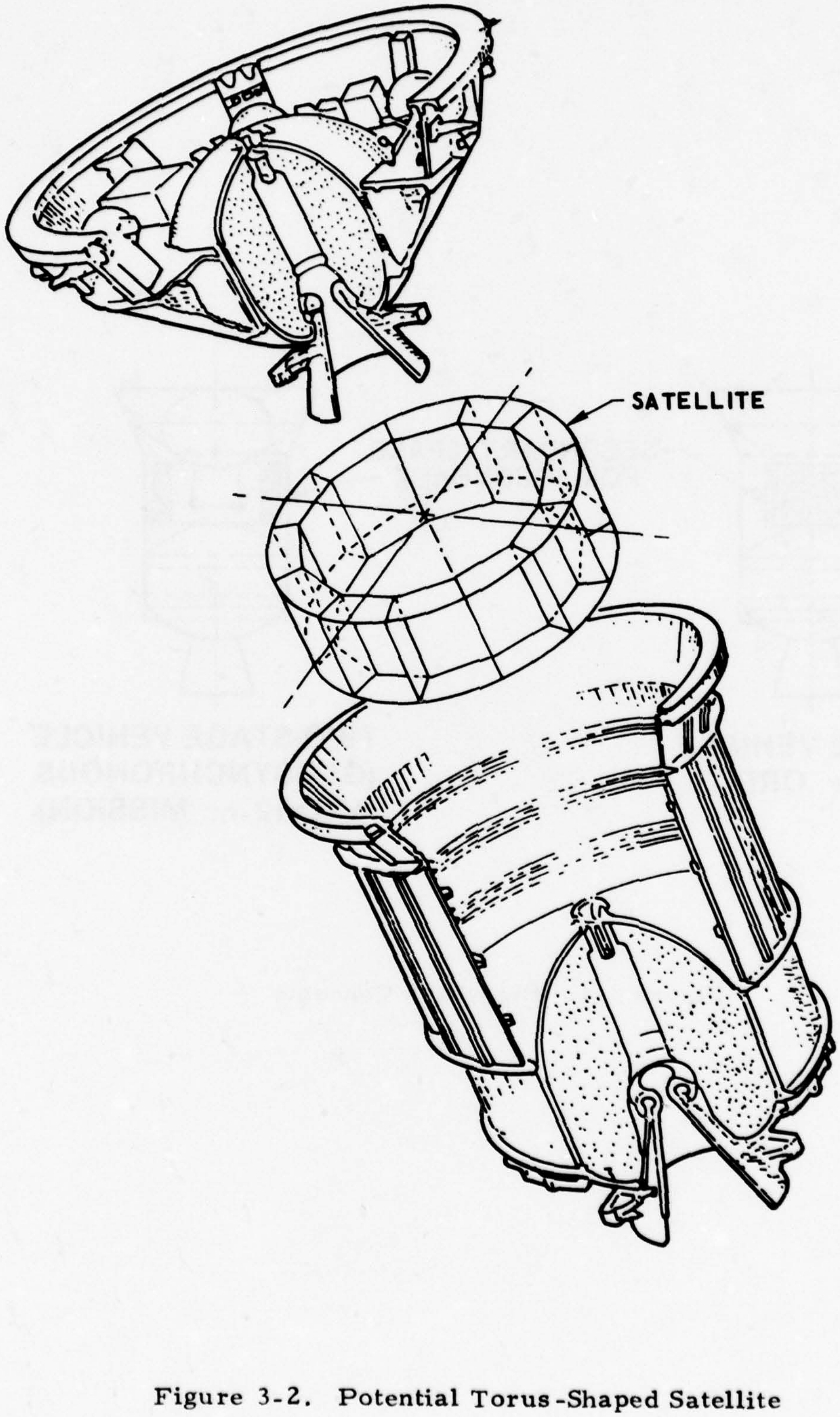


Figure 3-2. Potential Torus-Shaped Satellite

3.4 ENVIRONMENTAL RESEARCH SATELLITE

There is a continuing strong DoD need for space environment data provided by the smaller research experiments. Although the actual weight, power, and telemetry requirements of most of the research type experiments are often very modest, their relative value far outweighs what might be expected on this basis. Their importance also tends to be overlooked because these experiments are rarely tied directly to specific operational systems, but rather to more general DoD requirements. On the other hand, the operational use of a Mini-HALO system is apparent, and such experiments quickly receive high priority for space flight. Consequently, the support for a separate budget line item for funds is more easily maintained. The funding problems of small research experiments were recognized when STP policy was formulated. This policy provides for space flight when experiments are not separately funded for their own vehicles.

In recent years, an increasing number of large, systems-oriented experiments have been scheduled at the expense of these research experiments which constitute some 60 percent of the experiments awaiting space flight. As funds are used for the primary experiments, less is available to support secondary experiments. Although it is a policy to schedule these secondaries on primary missions, an insufficient number can be accommodated.

A number of major DoD and contractor laboratories have many programs tied to DoD space research experiments addressing problems associated with communication, surveillance, and survivability, and the results from these experiments provide information for the definition of future DoD space systems. The secondary STP satellite S3-3, for example, was an outstanding success. A complement of synergistically related experiments showed the existence and measured, for the first time, electric fields and related ion drifts in auroral forms. Such data will aid greatly in understanding polar ionospheric phenomena and the related effects on communications in the polar regions.

It is proposed that an environmental research space flight, similar to the S3 series, be scheduled in the Five Year Plan. A high-inclination, elliptical orbit, which is uncommon for primary spacecraft, would satisfy a number of related ionospheric and magnetospheric experiments. This mission would be planned for flight in FY 1985. The following group of experiments are good candidates although final selection has not been made: ONR 805 PIE-2, CRL 254 Ionosphere-Plasma Coupling, CRLS 232 Energetic Protons, NRL 604 Photoelectron Airglow, and CRLS 252 Artificially Disturbed Ionosphere. The satellite would be spinning and placed in a high inclination and highly elliptical orbit from the Shuttle using the Teal Ruby/ GPS transfer stage. Thus, the Teal Ruby cradle would be well suited for supporting the satellite for the Shuttle portion of the ride. The satellite could be the SCS spacecraft design as described in Appendix A. Such a potential configuration is shown in Figure 3-3. A cost estimate for this mission is shown in Table 3-3.

Table 3-3. Estimated Cost for the Environmental Research Spaceflight[a]

Item	1978 $ Million
Spacecraft	
Transfer Stage	
Cradle	
Experiment Integration	
Shuttle Integration	
On-Orbit service	
Total	

[a]As noted on the inside front cover, cost figures have been deleted.

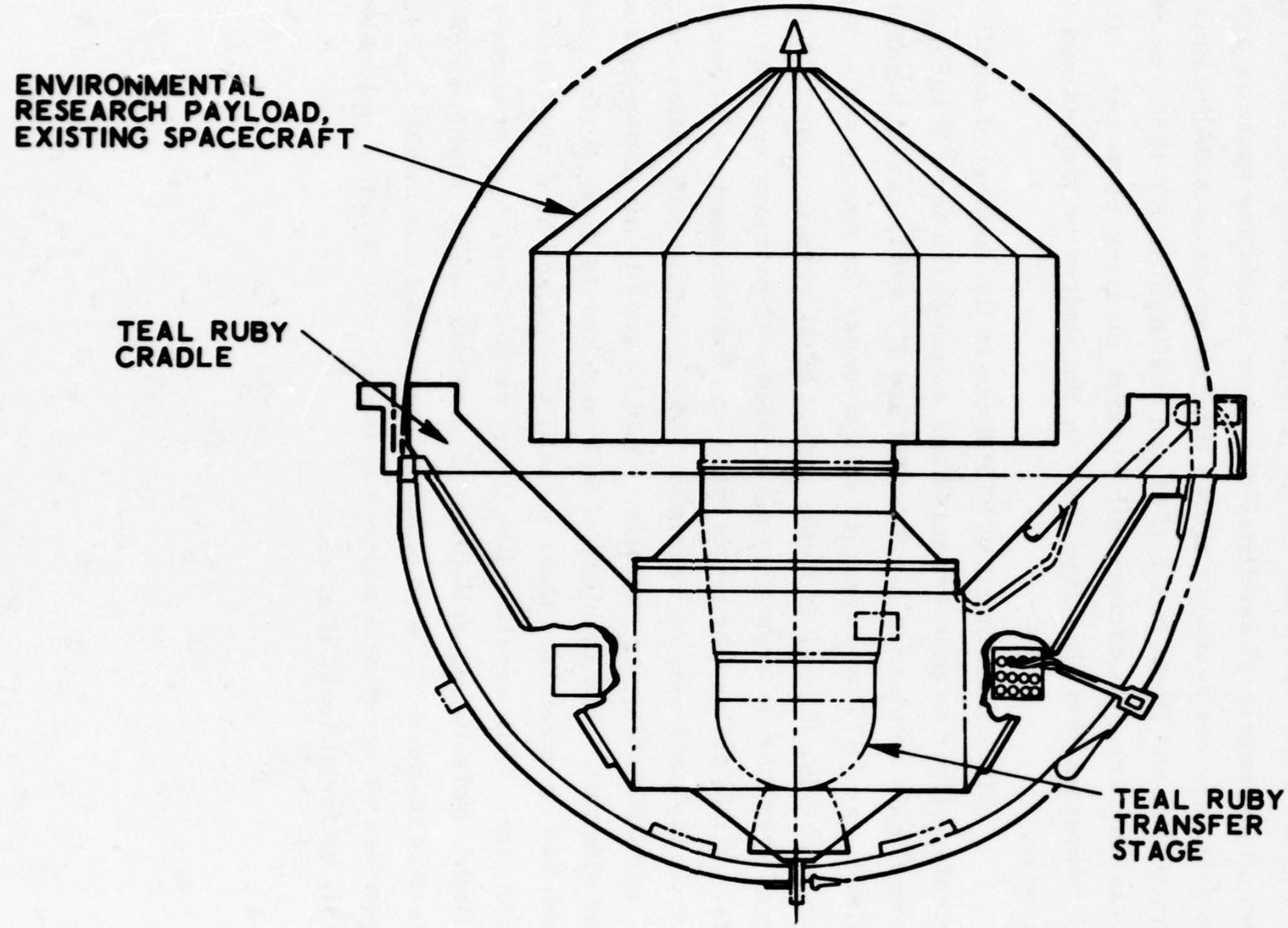


Figure 3-3. Potential Configuration for the Environmental Research Satellite

In addition, a separate budget line of $1.5 to $2 million is proposed in the Five Year Plan for the purpose of flying piggyback experiments on other programs' satellites whenever secondary space is available Definite dates are not available at this time as space availability must be determined, but one flight in FY 1981 and one flight in FY 1983 are reasonable goals and are satisfactory for present planning purposes. It is considered important that this line item in the budget be maintained for this purpose.

The commitment of STP funds to the support of small research experiments, either as primary missions as proposed for FY 1985, or as secondary flights as planned for FY 1981 and FY 1983, cannot be overemphasized. For STP to regain its effectiveness for timely space flight of research payloads, these line items cannot be allowed to evaporate simply because of overruns or urgencies associated with primary systems oriented payloads. If this philosophy is accepted and implemented, effective planning of research payloads may be regained. The schedule difficulties encountered by E^2S^2 and Dismedia, for example, could be greatly mitigated by such advanced planning. The inability of STP to schedule these during solar maximum has compromised their scientific value and no doubt frustrated their sponsors. With separate line items established, four or more years before flight, orderly and well-planned missions can be implemented in a cost effective manner. If such planning must await last minute lobbying from sponsors or accidental sources of funds, cost effective implementation would only be fortuitous, if at all.

4. RECOMMENDATIONS AND IMPACTS

4.1 RECOMMENDATIONS

Based on the study, the STP recommends the following for the first five years of Shuttle operations:

4.1.1 PROCURE COMMON SUPPORT EQUIPMENT (CSE)

The procurement consists of three phases. The initial two phases consist of procuring limited hardware to fulfill the needs of the first two sortie missions. These phases are followed by a third which augments the hardware to the final configuration.

4.1.2 PROVIDE ASTRONAUT TRAINING

Astronaut training provided by the STP relates only to the use of MASE (manned aerospace support equipment) in conjunction with experiment operations. The payload specialist is provided by the experimenter, and the training on life support and emergency routines is provided by NASA.

4.1.3 CREATE SECONDARY FLIGHT OPPORTUNITIES

New procurements for the Shuttle era, such as the IUS (Inertial Upper Stage) and the block change of GPS (Global Positioning System) and DMSP (Defense Meteorological Satellite), should consider accommodations of secondary (or piggyback) experiments for STP in their design.

4.1.4 PLAN AND BUDGET FOR ENVIRONMENTAL RESEARCH SPACE FLIGHTS

Environmental research spaceflights, at a frequency of one every two or three years, are considered adequate. This frequency is satisfied by one primary flight and two secondary (or piggyback) flights through FY 1985.

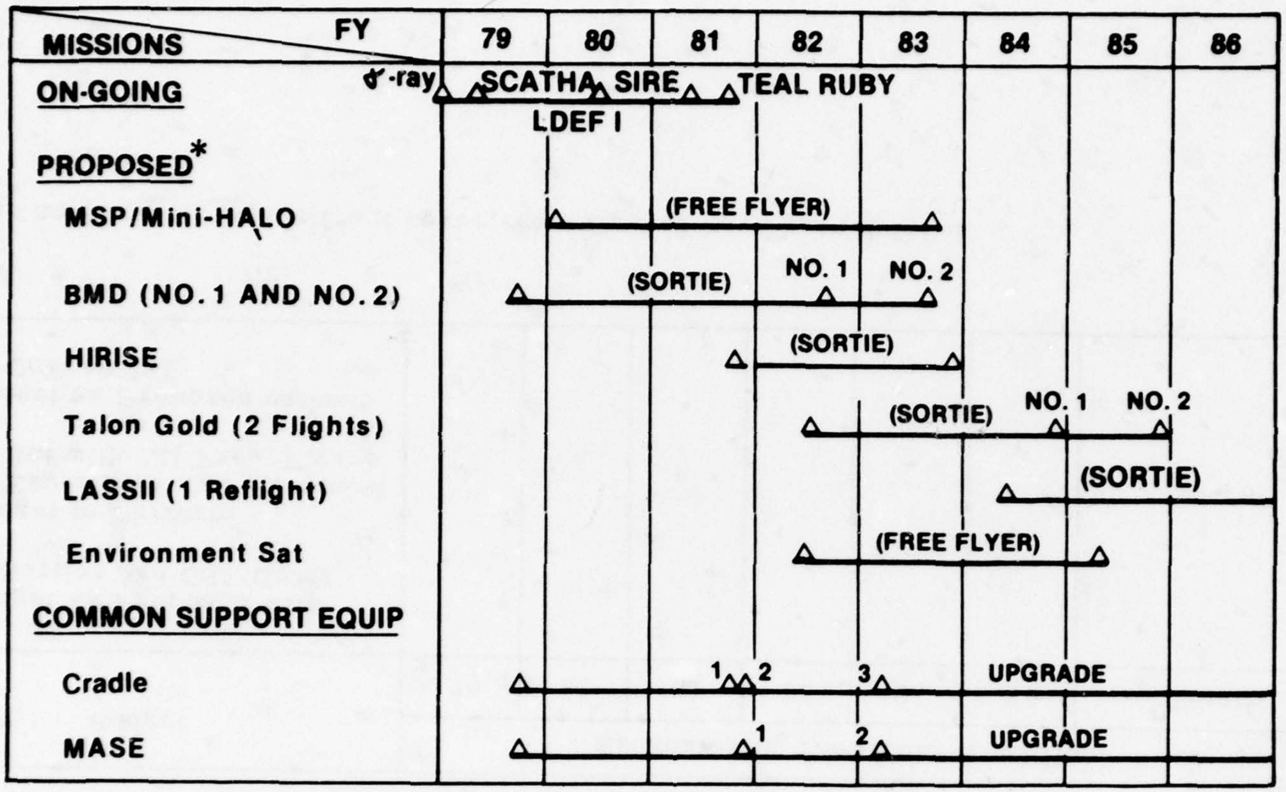
4.2 IMPACTS

In the proposed STP schedule (Figure 4-1), the launch date for the first BMD flight (FY 1982) is one year later than the sponsor's desired date. The later date is primarily dictated by availability of the common support equipment as seen in the procurement schedule of Figure 2-5 (see Section 2).

The technical specifications for the cradle and interface equipment can be generated on the basis of the studies performed in the past year, but the MASE technical requirements are yet to be established. Thus, studying requirements, generating specifications for procurement, evaluating proposals, and selecting a contractor put the contract start date at late FY 1979. It is envisioned that both the cradle and MASE will be procured under one contract and the period of performance will be two years. Thus, the first set of common support equipment will be available at the end of FY 1981. Following that, a nine-month period is scheduled for experiment integration and integration into the Shuttle system.

This plan is also influenced by an STP self-imposed guideline of keeping down the budget impact. The schedule for CSE can perhaps be accelerated somewhat (although STP does not recommend it), but it must be accompanied by a budget increase in the early years. To minimize budget impact, STP further assumes, on the basis of discussions with the sponsors of the first two sortie missions, that supplemental funds can be made available. The current STP approved program budget is inadequate to support the Five Year Plan and needs to be augmented. Cost sharing by experiment sponsors for the purpose of augmenting the STP program is discussed in Appendix D.

Finally, one observation is in order. Suppose the three proposed sortie missions were flown as free-flyers. The costs of Table 2-1 (see Section 2) for the free-flyer mode were inflated according to the schedule in Figure 4-1 and totaled in Table 4-1. In Table 4-1 the all free-flyer costs are compared with the proposed budget (assuming no supplemental funding from sponsors). It is seen that the sortie mode of flight



*These missions are assumed for purposes of budget planning and CSE procurement strategy

Figure 4-1. STP Schedule

Table 4-1. Free Flyer vs. Sortie Cost Comparison[a]

Budget	Estimates in Then Year $ Million						
	79	80	81	82	83	84	Total
Budget as Proposed with Sorties and CSE Costs							
Budget to Perform Experiments as Proposed But with All Free-Flyers							
Budget as Proposed without Cost of CSE							

[a] As noted on the inside front cover, cost figures have been deleted.

saves $ [1] million with CSE cost included. If the CSE were already available so that only refurbishment would be required before re-use, the sortie mode of flight would save $[1] million. This comparison demonstrates the benefits of the sortie flight mode as augmented by the CSE. This larger saving is realizable once the common support equipment is developed. It is of little doubt that the Five Year Plan as described in this report satisfies the study objective.

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[1] As noted on the inside front cover, cost figures have been deleted.

APPENDIX A

AVAILABLE SYSTEMS AND SERVICES

The Orbiter provides many systems and services to support a large variety of experiments. The following paragraphs briefly outline the available systems and services that will provide this support for STP missions. For more detailed information see the bibliography.

A. 1 SYSTEMS

A. 1. 1 Spacelab

Spacelab is a general-purpose orbiting laboratory for manned and automated activities in near-earth orbit. Involvement of ground-based scientific personnel in direct planning and flight support is an integral part of this program.

The Spacelab consists of module and pallet sections used in various configurations to suit the needs of a particular mission. The pressurized module, accessible from the Orbiter cabin through a transfer tunnel, provides a shirtsleeve working environment.

The module consists of one or more pressurized cylindrical segments, each with a 13-ft, 4-in. diameter and an 8-ft, 7-in. length, and two end cones. The forward end cone is truncated at the diameter required to interface with the crew transfer tunnel. The first, and sometimes only, cylinder is called the core segment (Figure A-1). Spacelab subsystem equipment, including all housekeeping equipment, occupies about 40 percent of its volume, leaving about 60 percent available for experiments. An astronaut can work in this core segment. When additional volume is needed, another cylinder, called the experiment segment, is added. All of the volume in experiment segments is available for experiments.

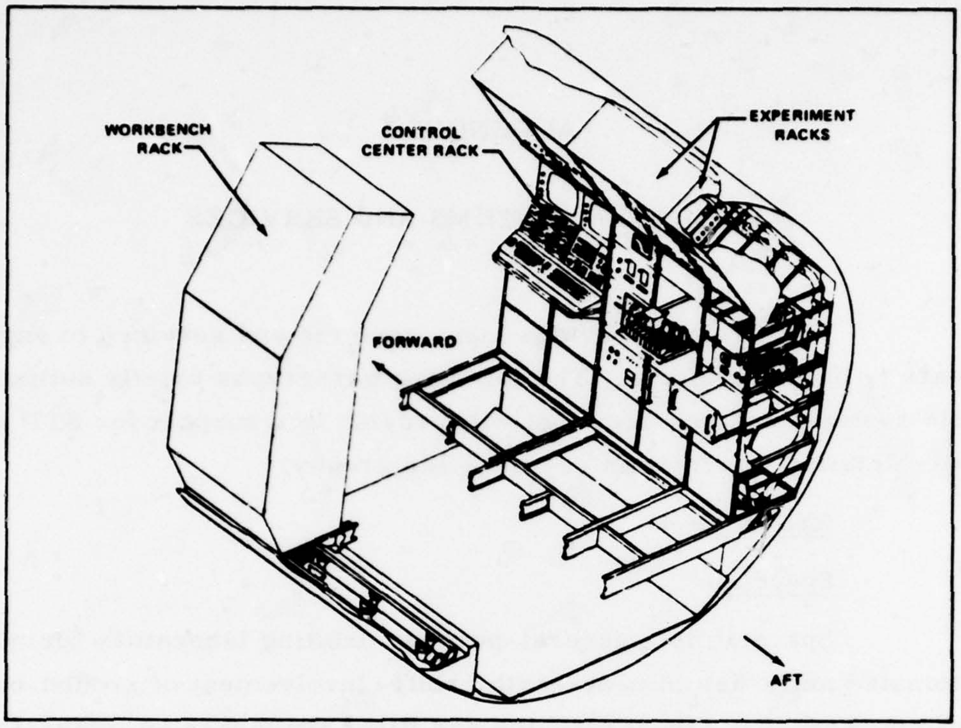


Figure A-1. Core Segment Cutaway View (Starboard)

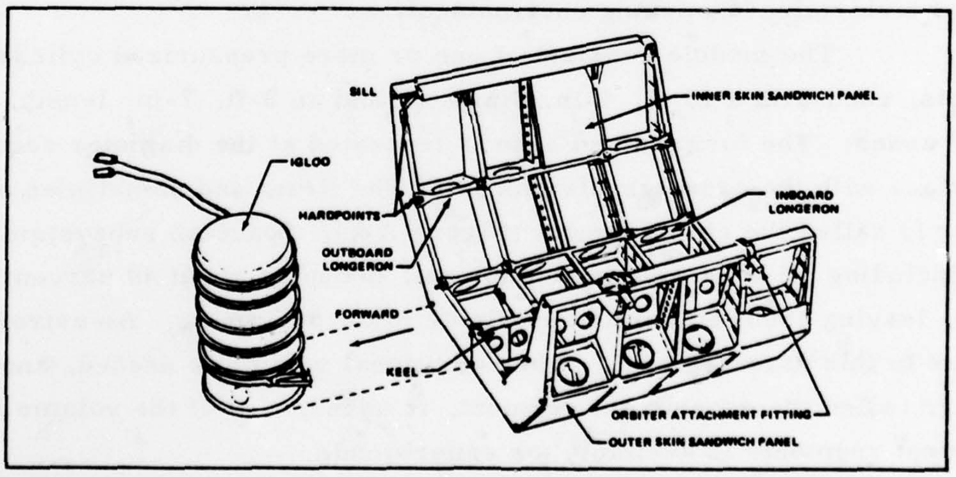


Figure A-2. Pellet Segment and Igloo

A pallet is a U-shaped structure that accommodates experiment equipment for direct exposure to space. Each standard pallet segment is 9.8 ft long. Two or three can be connected to form a single pallet train, supported by one set of retention fittings. When no module is used, a cylindrical "igloo," mounted on the end of the forward pallet, provides a controlled, pressurized environment for Spacelab subsystems normally carried in the core segment (Figure A-2). Or, the pallet can be equipped to be self-contained and partially or fully autonomous from the Orbiter.

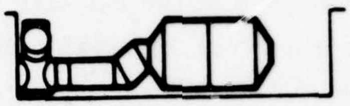
When the module is used, primary control of scientific equipment will be from the module itself. A Payload Operations Control Center on the ground will function in a support and advisory capacity to on-board activity. In a pallet-only configuration, equipment is operated remotely from the Orbiter aft flight deck or from the ground. The basic configurations available are discussed below and are shown in Figure A-3.

A.1.1.1 Long or Short Pressurized Module Alone

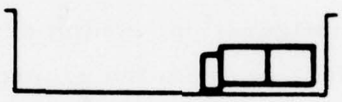
A short module consists of a core segment only. A long module consists of a core segment and one experiment segment placed end to end. Such a long module arrangement is shown at the top of Figure A-3. It can provide up to 784 ft^3 for experiments. Modules for all flight configurations contain the same basic internal arrangement of subsystem equipment; the main difference is the volume available for experiment equipment installation.

Mission-dependent experiment racks are available for experiments, experiment switching panels, remote acquisition units, intercom stations, and similar equipment. The standard 19-in. racks can accommodate laboratory equipment. Additionally, the module can be fitted with mission dependent items including top airlock and optical window/viewpoint assemblies.

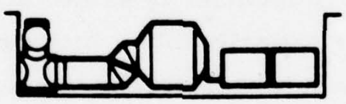
(1) Pressurized Module Alone



(2) Pallet(s) with Igloo



(3) Pressurized Module Plus One or More Pallets



(4) Pallet Alone

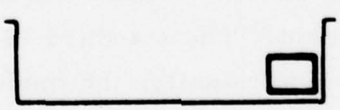


Figure A-3. Basic Spacelab Configurations

A. 1. 1. 2 Pallet(s) with Igloo

The standard U-shaped pallets are of aeronautic-type construction covered with aluminum panels. These panels can be used for mounting lightweight payload equipment. A series of hardpoints attached to the main structure of a pallet allows mounting of heavy payload items.

The pallet provides basic services, such as subsystem and experiment electric power buses and distributions, data buses, cold plates, thermal capacitors, and plumbing.

In the pallet-with-igloo configuration (one to five pallets with at least one igloo and no module), the Spacelab subsystem equipment that is ordinarily in the module is installed in the igloo. The igloo, pressurized to 1.0 standard atmosphere, has a usable volume of 77.69 ft^3. Figure A-3 illustrates the pallet-with-igloo configuration.

A. 1. 1. 3 Pressurized Module Plus One or More Pallets

As shown in Figure A-3, this configuration provides the additional equipment mounting area of the pallet with services supplied from the pressurized module.

A. 1. 1. 4 Pallet Alone

The pallet-alone configuration provides mounting support to experiments and support equipment. Pallets can be used in combination with any of the other configurations described above, thus allowing partial or near-autonomy from the Orbiter interfaces.

A. 1. 2 Pointers

Several pointing systems are available for use by experimenters. These systems are added to the Orbiter bay support structures to increase experiment pointing stability, provide a freedom of pointing direction, and/or provide more rapid and economic slewing ability than could be obtained by Orbiter maneuvers. The pointing systems are described in the following.

A. 1. 2. 1 Instrument Pointing Subsystem (IPS)

The IPS is a gimbal system attached to the payload when on orbit. It performs the control maneuvers required by the observation program and can accommodate a wide range of payload instruments of different sizes and weights.

During ascent and descent, the payload is physically separated from the IPS to avoid imposing flight loads from the IPS to the payload. The payload is supported by the payload clamp assembly, which distributes the flight loads of the payload into the pallet hardpoints. The payload clamp assembly is capable of mounting and distributing the load of a nominal 4410-lb payload and the IPS into a single unmodified pallet without exceeding safe loading conditions.

The IPS provides three-axis attitude control and stabilization for experiments whose characteristics are encompassed in Table A-1. Pointing and stabilizing characteristics are summarized in Table A-2.

Overall control of the IPS during normal operations may be exercised from the Spacelab console using the keyboard and display of the command and data management subsystems. The flight operating software is capable of interfacing through the Spacelab subsystem with the Orbiter data-handling system. Emergency retraction or jettison is exercised from a separate IPS control panel located on the Orbiter aft flight deck.

A. 1. 2. 2 Annular Suspension and Pointing System (ASPS)

The annular suspension and pointing system (ASPS) includes two assemblies with connecting interfaces, each assembly having a separate function (see Figure A-4). The first assembly is attached to the carrier vehicle and consists of an azimuth gimbal and an elevation gimbal which provide "coarse" pointing of the payload instrument by allowing two rotations of the instrument relative to the carrier vehicle.

Table A-1. Characteristics of Nominal Payloads with IPS

Parameter	Large payload	Small payload
Mass, lb (kg)	4410 (2000)	440 (200)
Dimensions, ft (m)	(2 by 4)	(1 by 1.5)
Moment of inertia about payload center of gravity, kgm^2		
About axis perpendicular to line of sight	1200	20
About line-of-sight axis	1000	25
Center of gravity offset from center of rotation of gimbal axes, ft (m)		
Along line of sight	6.6 (2.5)	4.9 (1.50)
Perpendicular to line of sight	1 (0.30)	0.33 (0.10)

Table A-2. IPS Pointing and Stability Characteristics

Parameter	Requirement	Goal	Comment
Pointing accuracy, arc sec			
Line of sight	2	0.8	1 sigma
Roll	40	15	1 sigma
Quiescent stability error, arc sec			
Line of sight	1	0.33	1 sigma
Roll	3	1.6	1 sigma
Crew motion disturbance[a] error, arc sec			
Line of sight	3	1	Peak
Roll	10	4	Peak
Stability rate			
Line of sight, arc min/sec	1	–	Peak
Roll, arc sec/sec	130	–	Peak
Line of sight, arc sec/sec	–	5	rms
Roll, arc sec/sec	–	25	rms
Pointing range, rad			
Line of sight	3.14 (or π)	N/A	
Roll	±3.14 (or π)	N/A	
Slewing rate, deg/sec	2.5		Maximum

[a]Corresponds to a typical wall push-off by a crewmember.

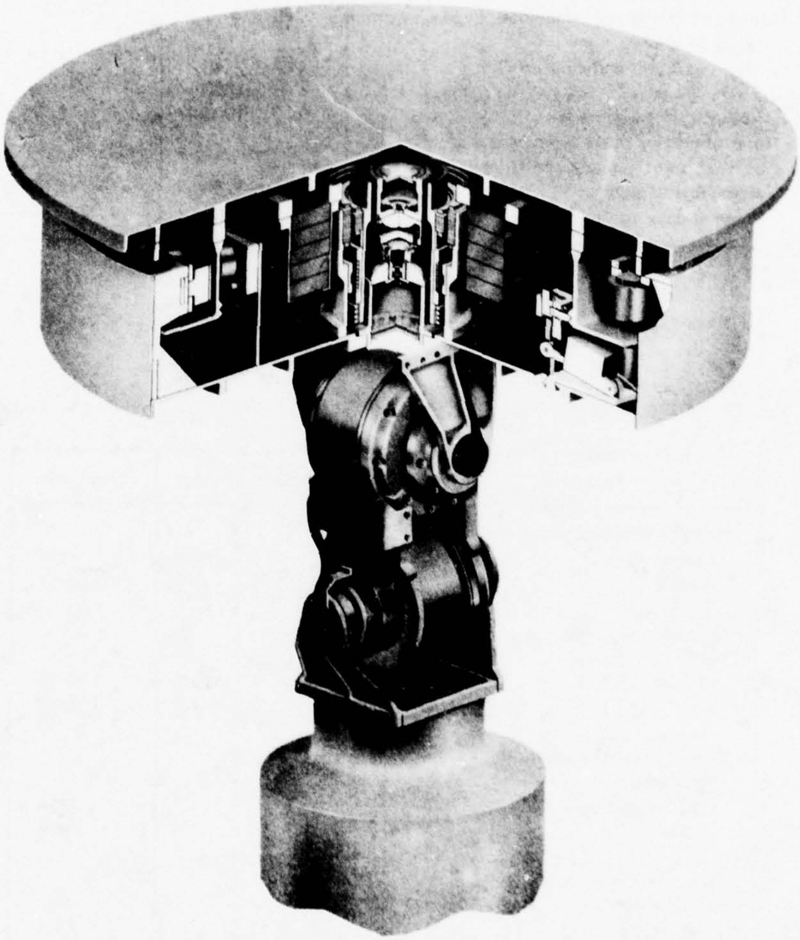


Figure A-4. Annular Suspension and Pointing System

The second or vernier pointing assembly is made up of magnetic actuators for suspension and fine pointing, roll motor segments, and an instrument mounting plate around which a continuous annular rim is attached which provides appropriate magnetic circuits for the actuators and the roll motor segments. The vernier pointing assembly is attached to the elevation gimbal and provides vernier attitude fine pointing and roll positioning of the instrument as well as six-degrees-of-freedom isolation from carrier motion disturbances.

ASPS characteristics are outlined in Table A-3 and support accommodations are listed in Table A-4.

A. 1. 3 Small Self-Contained Payloads ("Getaway-Special")

This system consists of a canister that holds the self-contained payloads and the canister's attachments to the Orbiter. Experiments under 200 lb and smaller than 5 ft^3 can be flown on a space-available basis. Costs for the "Getaway-Special" will be negotiated based on size and weight. Some limited Shuttle services; i.e., astronaut controlled "on-off" command of Spacelab power can be made available at an individually negotiated cost. A minimum volume of 1.5 ft^3 and a mass of 60 lb will be used to determine basic charges.

A. 1. 4 Remote Manipulator System (RMS)

The remote manipulator (Figure A-5) is standard equipment on the Orbiter and can be mounted to either the right or left longeron. A second manipulator arm can be provided as optional equipment, but the two systems cannot be operated simultaneously. Lights and television will be provided for illumination and viewing of RMS activities by the Orbiter crew.

A. 1. 5 Multimission Modular Spacecraft

The Multimission Modular Spacecraft (MMS) is a standard spacecraft developed by NASA Goddard Space Flight Center. It is capable of

Table A-3. ASPS Characteristics

Power (arc), W	89
Weight, lb	823
Size, in.	
Vernier system height	9.5
Overall height	46.25
Payload plate dia.	38
Vernier Pointing	
Pitch & yaw freedom, deg.	±0.75
Pointing stability (non-contact) arc sec	±0.01
Pointing stability (flux-wire), arc sec	±0.3
Roll angular freedom, deg.	±180
Course Gimbals	
Elevation angular freedom, deg.	±100
Lateral angular freedom, deg.	±60
Accuracy with internal sensor, arc min	±6

Table A-4. ASPS Payload Support Accommodations

Diameter and size, in.	38
CG offset, in.	59
Weight, lb	1320
Power, W	300
Energy, W-hr	300

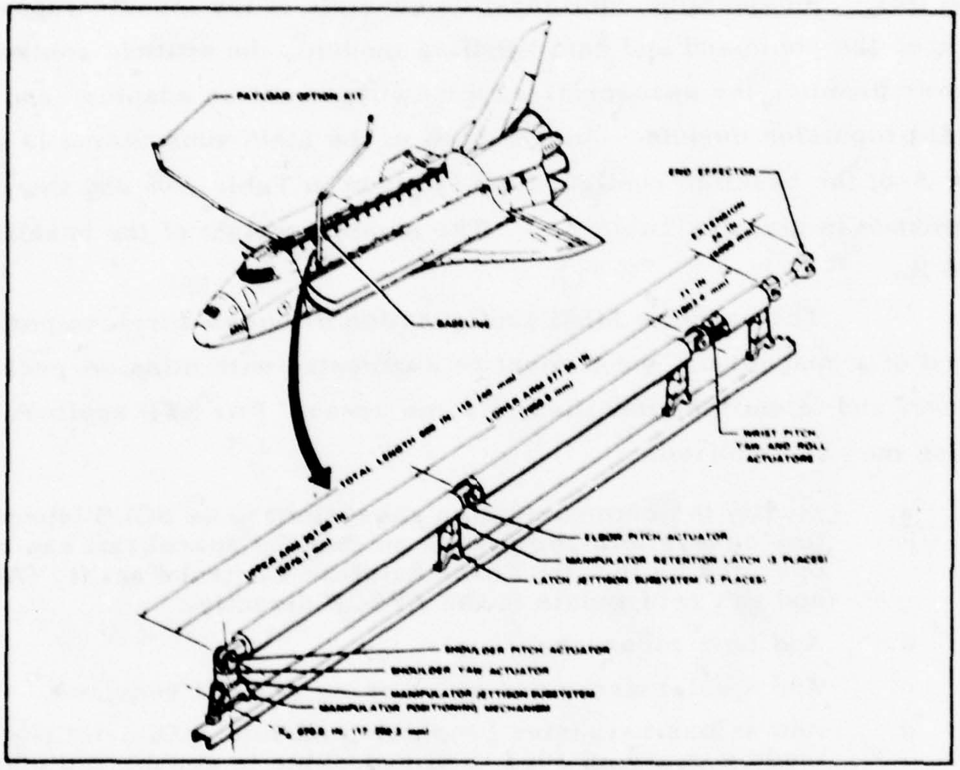


Figure A-5. Manipulator Arm Assembly and Location on Orbiter

supporting a variety of orbiting missions from low earth to geosynchronous altitudes. It can be launched by the Delta or the Shuttle.

The MMS is designed with retrieval and on-orbit servicing capabilities. The baseline configuration consists of the module support structure, the command and data handling module, the attitude control module, the power module, the spacecraft/experiment transition adapter, and an optional propulsion module. An overview of the MMS subsystems is shown in Figure A-6; the baseline configuration is given in Table A-5 and the general performance is given in Table A-6. The nominal weight of the baseline MMS is 1466 lb.

The baseline MMS configuration provides services nominally required of a spacecraft, but it must be augmented with mission-peculiar equipment and oftentimes modified in some areas. For STP applications, the following may be required:

a. Modify the communication subsystem to be SGLS (space ground link subsystem) compatible so that the spacecraft can be operated by the Air Force Satellite Control Facility (AFSCF) and can return data to the AFSCF directly.

b. Add tape recorders.

c. Add a solar array and solar array drive if required.

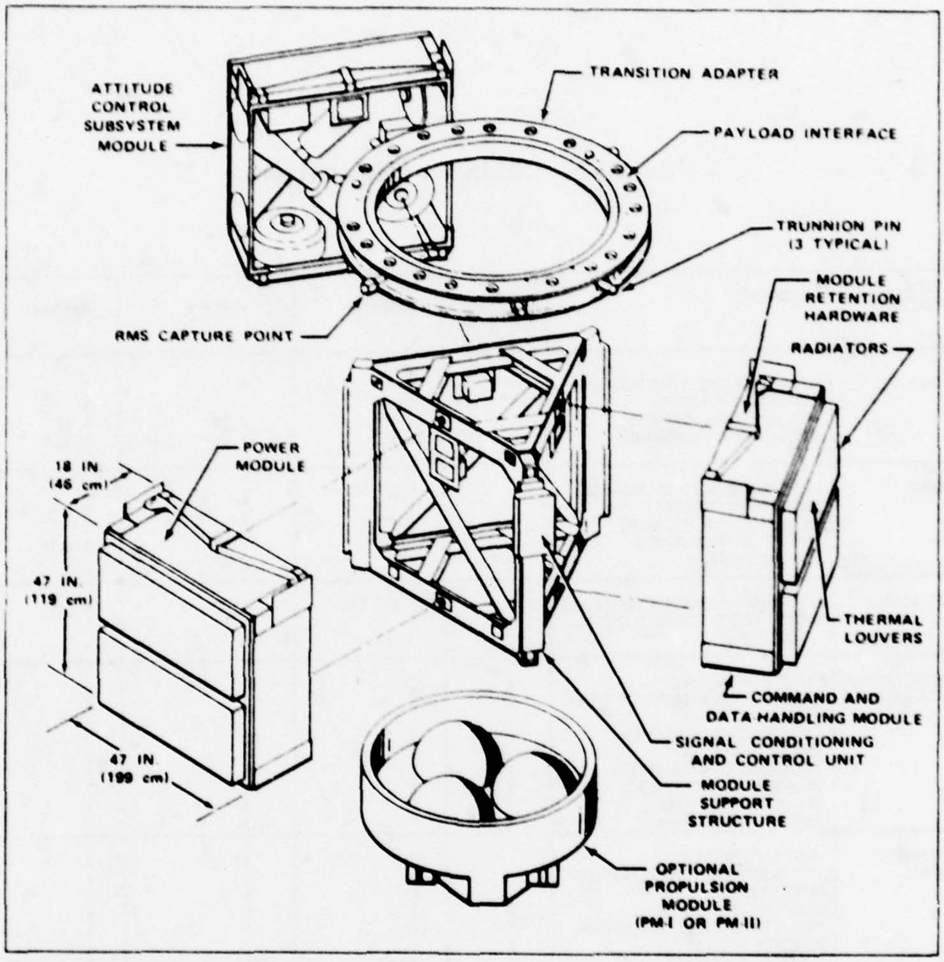
d. Add an orbit transfer propulsion module. An orbit transfer module carrying 1067 lb of hydrazine is considered optional by NASA but it is not presently under development.

e. Provide thermal and structural support of the experiment equipment.

The MMS system is also equipped with a flight support system that consists of a retention cradle, payload positioning platform, module exchange mechanism, and module magazine. For nonrecovery and nonservicing missions, only the retention cradle is needed.

A. 1. 6 Long Duration Exposure Facility

The Long Duration Exposure Facility (LDEF), being developed by the NASA Office of Aeronautics and Space Technology, is a recoverable



Modul?r mechanical subsystem components of the MMS.

Figure A-6. MMS Subsystems

Table A-5. MMS Configurations

SYSTEM / SUBSYSTEM	COMPONENT	NASA STANDARD COMPONENT	BASELINE	MINIMUM	MAXIMUM
MECHANICAL	MODULE SUPPORT STRUCTURE		1	1	1
	TRANSITION ADAPTER		1	1	1
	MODULE ATTACH HARDWARE		1 SET	1 SET	1 SET
	MISCELLANEOUS HARDWARE		1 SET	1 SET	1 SET
THERMAL	LOUVERS (MOUNTED ON MODULES)		6	6	6
	INSULATION (MODULES)		3	3	3
	INSULATION (SPACECRAFT)		1	1	1
	HEATERS & THERMOSTATS (TA & MODULES)		1 SET	1 SET	1 SET
ELECTRICAL	SPACECRAFT HARNESS & CONNECTORS		1 SET	1 SET	1 SET
	SIGNAL CONDITIONING & CONTROL UNIT		1	1	1
COMMUNICATIONS & DATA HANDLING	STACC CENTRAL UNIT	X	2	1	2
	STACC STANDARD COMPUTER INTER-FACE	X	2	1	2
	PREMODULATION PROCESSOR		2	2	2
	POWER CONTROL UNIT		2	2	2
	TRANSPONDER (STDN/TDRSS)	X	2	1	2
	ON-BOARD COMPUTER (OBC)	X	2	1	2
	OBC MEMORY (8K WORDS)	X	4	3	8
	REMOTE INTERFACE UNIT	X	2	1	2
ATTITUDE CONTROL	MAGNETIC TORQUERS		3*	3*	3*
	ATTITUDE CONTROL ELECTRONICS		1	1	1
	MAGNETOMETER		2	1	2
	STAR TRACKER	X	2	1	2
	PRECISION DIGITAL SUN SENSOR		1	1	1
	REACTION WHEELS	X	4	3	4
	INERTIAL REFERENCE UNIT	X	1	1	1
	REMOTE INTERFACE UNIT	X	2	2	2
	STAR TRACKER BAFFLES		2	1	2
	COARSE SUN SENSOR SET(MOUNTED EXTERNAL TO ACS MODULE)		2	1	2
POWER	BATTERY	X	2 20 A.H.	1 20 A.H.	3 50 A.H.
	POWER CONTROL UNIT		1	1	1
	POWER REGULATION UNIT	X	1	1	1
	BUS PROTECTION ASSEMBLY		1	1	1
	SIGNAL CONDITIONING ASSEMBLY		1	1	1
	REMOTE INTERFACE UNIT	X	2	1	2
INSTRUMENT MODULE EQUIPMENT	RIU	X	1	1	27
	BCU	X	1	1	7
	IM INTERFACE CONNECTOR		1	1	1

* YAW TORQUER CONSISTS OF 2 TORQUER BARS CONSIDERED AS ONE IN THIS LISTING

Table A-6. General MMS Performance Requirements

PAYLOAD WEIGHT CAPABILITY	4000 LBS. WITH EXPENDABLE LAUNCH VEHICLE; WEIGHT CAPABILITY WITH SHUTTLE IS SIGNIFICANTLY HIGHER THAN 10,000 LBS. AND LIMITED BY PAYLOAD CONFIGURATION.
TYPES OF MISSIONS	STELLAR, SOLAR, EARTH POINTED, OR SPECIAL PURPOSE MISSIONS; LOW EARTH OR GEOSYNCHRONOUS ORBITS: INERTIAL POINTED OR PAYLOAD POINTED.
OPERATING ORBITAL ALTITUDE	500 KM TO 1600 KM, ALL INCLINATIONS, AND GEOSYNCHRONOUS
LIFE EXPECTANCY/REDUNDANCY	NO DESIGN FEATURE SHALL PRECLUDE A MINIMUM TWO YEARS OF LIFE. SELECTABLE BETWEEN MINIMUM COMPONENT REDUNDANCY TO FULL REDUNDANCY BASELINE CONFIGURATION WHICH HAS NO SINGLE POINT FAILURE TO PREVENT RESUPPLY OR RETRIEVAL BY SHUTTLE.
LAUNCH VEHICLE	FULLY DELTA, ATLAS, TITAN, AND SHUTTLE COMPATIBLE. ALSO IUS LAUNCHED, SHUTTLE IN-ORBIT SERVICED AND SHUTTLE RETRIEVED.
<u>COMMUNICATIONS AND DATA HANDLING SUBSYSTEM</u>	
TRANSPONDER	S-BAND STDN/TDRSS, TRANSPONDER OUTPUT POWER AT ANTENNA PORT 1.0, 2.5, 5.0 WATTS, PRELAUNCH SELECTABLE.
COMMAND RATES	2 KBPS (SHUTTLE/STDN). 125 AND 1 KBPS SELECTABLE (TDRSS).
REAL-TIME TELEMETRY RATES	1, 2, 4, 8, 16, 32, 64 KBPS.
TELEMETRY FORMATS	2 SELECTABLE PRIOR TO LAUNCH, PLUS IN-ORBIT PROGRAMMABLE CAPABILITY; ALL FORMATS CONTAIN 890 DATA WORD MAXIMUM.
STORED DATA DUMP/MISSION DATA SOURCE	2.048 MBPS MAXIMUM, 1.024 MBPS CODED DATA.
ON-BOARD COMPUTER	16 BITS PER WORD. 32K WORDS OF MEMORY, BASELINE EXPANDABLE TO 64K WORDS. 5 MICROSECOND ADD TIME.
DATA STORAGE	STANDARD OPTION OF 10^8 AND 10^9 BIT TAPE RECORDERS.
<u>ATTITUDE CONTROL SYSTEMS</u>	
TYPE	3-AXIS STABILIZED, ZERO MOMENTUM
ATTITUDE REFERENCE (WITHOUT PAYLOAD SENSOR)	STELLAR (INERTIAL).
POINTING ERROR (ONE SIGMA)	
WITHOUT PAYLOAD SENSOR	$< 10^{-2}$ deg.
WITH PAYLOAD SENSOR (IDEAL)	$< 10^{-5}$ deg.
POINTING STABILITY (ONE SIGMA)	
AVERAGE RATE	$< 10^{-6}$ deg./sec.
JITTER	
WITHOUT PAYLOAD SENSOR	$< 6 \times 10^{-4}$ deg. (20 minute period)
WITH PAYLOAD SENSOR (IDEAL)	$< 10^{-6}$ deg.
SLEW RATE	BASED ON SPACECRAFT INERTIA; MAXIMUM 1.6°/SEC.
<u>POWER SUBSYSTEM</u>	
REGULATION OF LOAD BUS	$+28 \pm 7$ V DC
POWER OUTPUT	1200 WATTS AVERAGE (850 W AVAILABLE FOR USER), OR 1000 WATTS NOMINAL WITH A 2000 WATTS PEAK ON 10% ORBITAL DUTY CYCLE.
BATTERIES	TWO, 20-AMPERE-HOUR BATTERIES AS BASELINE AND UP TO THREE 50-AMPERE-HOUR BATTERIES MAXIMUM.
<u>PROPULSION SUBSYSTEM</u>	OPTIONAL ORBIT ADJUST AND REACTION CONTROL MODULE, (167 LBS. OF HYDRAZINE) OR ORBIT TRANSFER MODULE, (1067 LBS. OF HYDRAZINE).

unmanned, gravity-gradient-stabilized, free-flying structure on which many different experiments can be mounted. The structure consists of a 30-ft-long, 14-ft-diameter framework, with 72 experiment trays on the periphery and two trays on each end as shown in Figure A-7.

The Shuttle places the LDEF in earth orbit, where it remains for six months or more until another Shuttle flight retrieves it and returns it to earth. A manually operated manipulator system is used in both deploying and retrieving the LDEF. The LDEF is released into a circular orbit of approximately 300 nmi with an inclination to the equatorial plane between 28.5 deg and 57 deg. Gravity gradient stabilization is with respect to three axes; thus experiments have zenith-, nadir-, ram-, wake-, and lateral-looking opportunities. Upon landing, the LDEF will be removed from the Shuttle payload bay and the experiments will be removed from LDEF and returned to the experimenters for analyses.

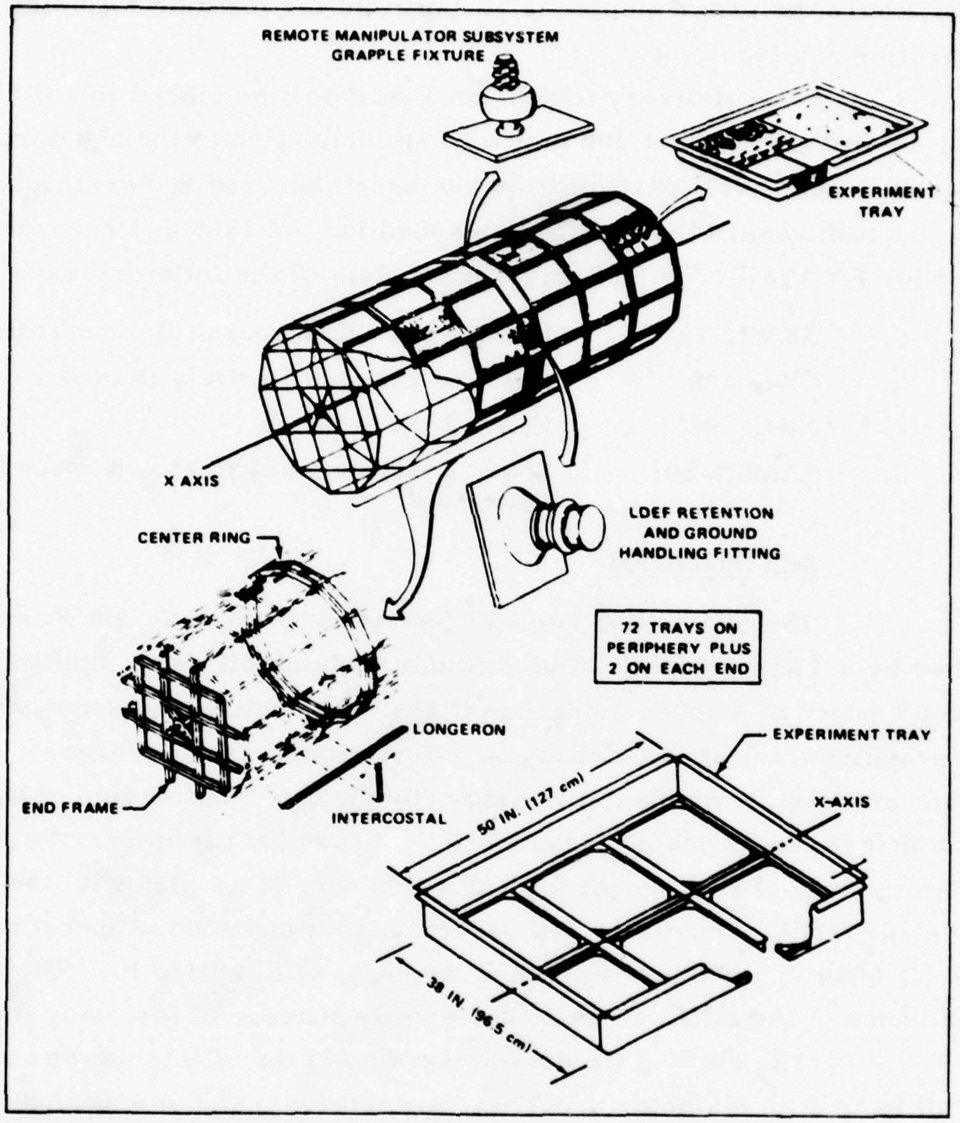
Experiments for LDEF can be either passive or active. For passive experiments, measurements will be made in a ground laboratory before and after exposure to the space conditions. For active experiments, the data gathering may require such active systems as power, data storage, and a mechanized vacuum canister.

For experiments with an identified need, the LDEF Project Office can make available certain experiment support items. Two items of common equipment are currently being developed:

a. Electrical Power and Data System (EPDS)

b. Experiment Environment Control Canister (EECC)

The EPDS is applicable to those experiments that require a number of measurements a few times each day during the course of an LDEF flight. The EECC canister provides a means of maintaining a clean, low pressure environment during ground operations together with the opportunity to control the duration of an exposure to space conditions. The integration of the experiment tray (or trays) can be carried out at the experimenter's



Structural characteristics of LDEF and experiment trays.

Figure A-7. Long Duration Exposure Facility

facility, where the experimenter is responsible for the total experimental configuration and functions.

In the delivery flight, the LDEF will be placed in a circular orbit at an altitude of about 300 nmi with an inclination to the equatorial plane of 28.5 deg. STP participation has been approved and designated S80-1. Launch aboard the Shuttle is planned for FY 1980 and recovery planned for FY 1981. The STP payload consists of the following experiments:

a.	AFWL-701	Fiber Optics Spaceborne Demonstration
b.	CRL-258	Passive Trapped Particle Detector
c.	NRL-702	Heavy Ions in Space
d.	SAMSO-802	Space Environment Effects on Spacecraft Materials

A.1.7 SCS Spacecraft

The SCS is the Satellite Control Section of an Air Force vehicle launched by a Titan booster. The SCS unit contains all the equipment necessary for control of a space vehicle in flight. An orbit-adjust subsystem provides propulsion for altitude changes, correction of velocity errors, drag makeup, and vehicle deorbit at mission completion. The design of the SCS is such that it can be readily adapted to the Space Shuttle to perform essentially every type of near-earth orbit mission and, if coupled with the inertial upper stage (IUS), potentially will provide a geosynchronous spacecraft in excess of 6000 lb. The dry weight of the basic SCS is 3152 lb. The on-orbit performance of the SCS has been consistently successful for many flights.

The current production version of the SCS is shown in Figure A-8. It is 10 ft in diameter and 97 in. overall from end of engine nozzle to forward payload mounting face. Deployable solar arrays are mounted on the aft bulkhead of the orbit-adjust section. Payloads limited only by Shuttle constraints can be mounted on the large forward bulkhead. The SCS is a completely maneuverable spacecraft and has a full complement of redundant reaction control hydrazine thrusters.

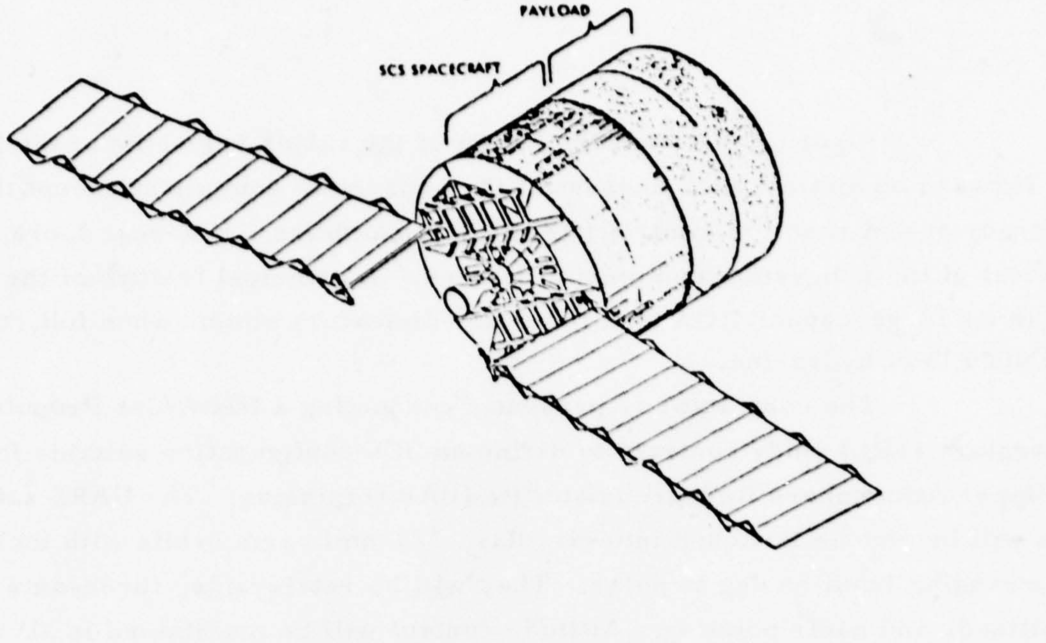


Figure A-8. Baseline Satellite Control Section (SCS) Flight Configuration

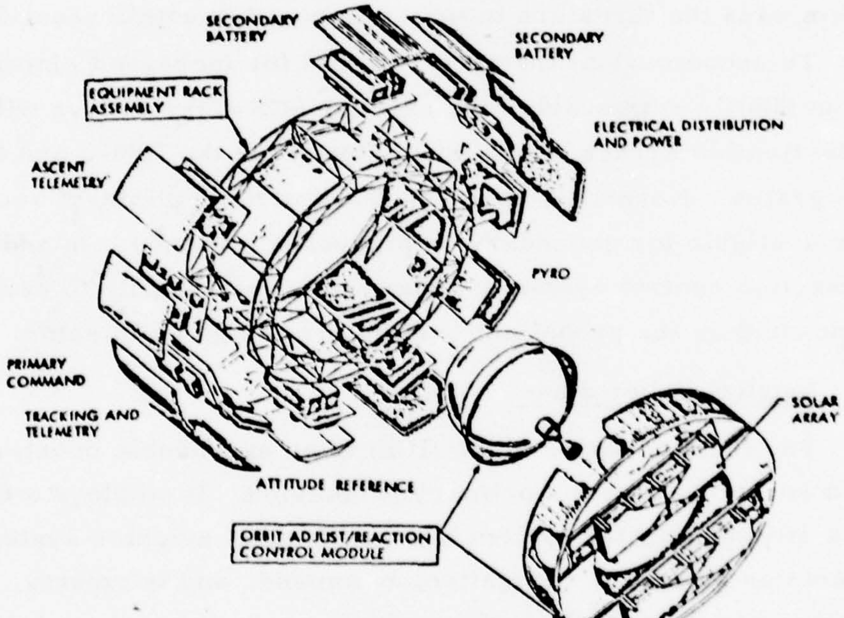


Figure A-9. Baseline Satellite Control Section (SCS)

Figure A-9 shows the layout of the major segments of the SCS. The forward equipment rack houses all the subsystem equipment except the orbit-adjust and reaction-control (OA/RCS) assemblies. External doors allow removal of the subsystem equipment modules. A principal feature of the SCS is its large-capacity OA tank (62.5-in. diameter) which, when full, carries 4000 lb of hydrazine.

The contractor is presently conducting a NASA/Jet Propulsion Laboratory (JPL) study contract to define an SCS configuration suitable for the Upper Atmosphere Research Satellite (UARS) mission. The UARS satellites will be Shuttle launched into circular, 323-nmi earth orbits with inclinations ranging from 56 deg to polar. They will be retrievable, three-axis stabilized, and nadir pointing. Attitude control will be maintained in all three axes to within 0.01 deg and rotation rates will be constant to within 0.0007 deg/sec. For UARS, star trackers and reaction wheels will replace the horizon sensor and hydrazine Reaction Control System (RCS) thrusters (the baseline system uses the thrusters to maintain pointing within about 0.3 deg).

To accommodate the requirements for increased electrical power and to be Shuttle retrievable, the existing SCS solar arrays will be replaced by the flexible arrays of the type planned for the P80-2 and Space Telescope Programs. Normally, three or more of the equipment rack bays of the SCS are available for secondary or piggyback payloads. In addition, a few of the reaction control system bays are usually available to carry experiments depending on the propellant loading for any given mission.

A.1.8 Inertial Upper Stage

The Inertial Upper Stage (IUS) is an expendable booster vehicle that uses solid rocket motors for primary propulsion. It employs a three-axis stabilized attitude control system and a redundant avionics system capable of precision guidance, navigation, command, and telemetry. Spacecraft are cantilevered from the interface adapter and all services to and from

the spacecraft are through the IUS. Deployment is by means of the remote manipulator system or a self-deployment mechanism.

There are a number of configurations planned for the IUS using various combinations of the two solid rocket motors (Figure A-10). The smaller of the two motors will optionally contain 4300 to 8000 lb of propellant; the larger motor may be loaded with 15,500 to 21,400 lb of propellant.

Mission and performance designs of four of the basic IUS configurations are shown in Figure A-10. In addition, and of particular interest to the STP, the single-stage IUS vehicle can place about 12,000 lb into a 12-hr elliptical orbit with 21,450-nmi apogee. Also when a maximally loaded SCS spacecraft is coupled with the twin-stage IUS, the on-orbit weight (SCS Spacecraft and experiment) is 8200 lb for a 24-hr orbit and 7000 lb for a 24-hr orbit with zero degree inclination. This performance capability exists as a result of the SCS capability to load 8000 lb of hydrazine for propulsion.

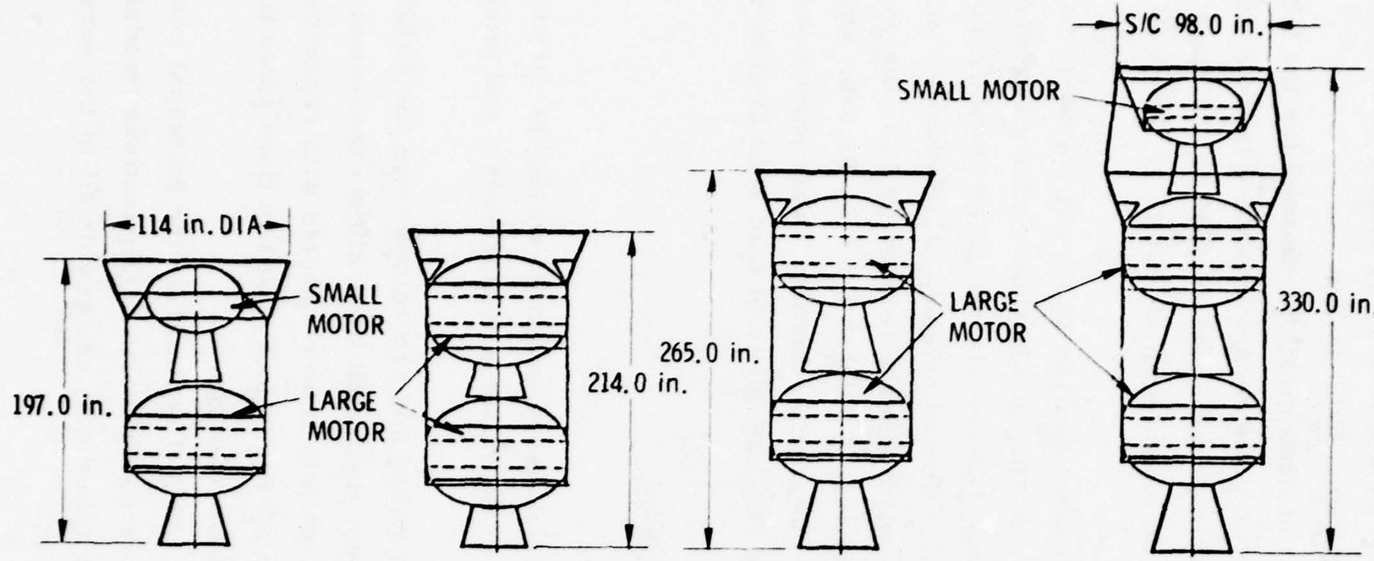
A.2 AVAILABLE SERVICES

A.2.1 Utilities

A wide range of services are available within the Orbiter. The extent of these services depends on the mission requirements and total complement of the payload.

Utility lines are provided and are routed from the Orbiter to the Spacelab interface. Experiment-dedicated lines allow experiment equipment (both in the module and on a pallet) to be connected with experiment-supplied equipment in the Orbiter aft flight deck. Utility lines from the interfaces must be provided as part of the experiment.

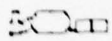
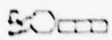
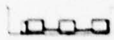
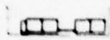
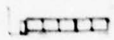
Tables A-7, A-8, and A-9 summarize the principal resources available from the Orbiter. Any of the Spacelab configurations (module, module with pallet, or pallet with igloo) may use any or all of the services as



	TWO-STAGE VEHICLE (Geosynchronous Mission)	DOD TWIN-STAGE VEHICLE (12-hour orbit)	NASA TWIN-STAGE VEHICLE (low-energy planetary)	THREE-STAGE SPINNER (high-energy planetary)
• MISSION	DOD	DOD	NASA PL-34A (Mars Mobile Lander)	NASA PL-22A (Saturn/Uranus & Jupiter Orbiter)
• PAYLOAD (lb)	5000	6000	11,023	1,124 (Saturn/Uranus Mission) 3,307 (Jupiter Orbiter)

Figure A-10. Planned IUS Configurations Using Combinations of Two Solid Rocket Motors

Table A-7. Electrical Power and Energy Resources for Payloads

Configuration	Parameter		
	Energy available to payload during flight, kWh (MJ)[a]	On-orbit power at electrical power distribution subsystem interface, kW[b]	
		Maximum continuous	Peak[c]
	123.2 (443.5)	2.5	6.9
	59.2 (213.1)	2.0	6.4
	55.2 (198.7)	2.0	6.4
	65.2 (234.7)	2.1	6.5
	62.2 (224)	2.1	6.5
	457.6 (1647.4)	4.6	9.4
	455.6 (1640.2)	4.6	9.4
	453.6 (1633)	4.5	9.3

[a]From basic 890 kWh (3204 MJ) Orbiter supply. Additional energy is available only by decreasing the mass capacity for experiments.

[b]With operation of mission-dependent nondiscretionary equipment. In addition, figures for all module configurations assume approximately 1 kW of power is available because some discretionary subsystem and mission-dependent equipment is not powered.

[c]15 minutes duration for 3-hour intervals.

Table A-8. Heat Rejection Capabilities and Module Atmosphere Aspects

Parameter	Configuration	
	Module	Pallet
Atmosphere		(Igloo)
Nominal total pressure, bar (N/m²)	1.013 ± 0.13 (101 300 ± 13 000)	1.096 (9600)[a]
Partial oxygen pressure nominal, bar (N/m²)	.220 ± .017 (22 000 ± 17 000)	.035 (3500)[b]
Partial carbon dioxide pressure nominal, bar (N/m²)	.0067 (670)	
Cabin air temperature, °F (K)	64 to 81 (291 to 300)	95 (308)[c]
Minimum humidity (dewpoint), °F (K)	43 (279)	
Maximum relative humidity, percent	70	
Maximum allowable internal wall temperature, °F (K)	113 (318)	
Air velocity in habitable area, ft/sec (m/sec)	0.33 to 0.66 (0.1 to 0.2)	
Total heat transport capability,[d] kW	8.5	8.5
Prelaunch/postlanding power,[d] kW		
GSE connected		
Orbiter powered down	Same as operational phase	
Orbiter powered up	1.5	1.5
Ascent/descent	1.5	1.5
Peak heat rejection capability[d]		
For payload power peaks during operational phase, kW	12.4	12.4
Minimum interval between peaks, min	165	165

[a]Maximum gaseous nitrogen differential pressure.
[b]Minimum gaseous nitrogen differential pressure.
[c]Maximum internal temperature.
[d]Available to payload and Spacelab subsystems.

Table A-9. Command and Data Handling Resources

Payload data acquisition	
Housekeeping and low rate scientific data (to computer via RAU's)	
Number of remote acquisition units (RAU's) of basic system	8
Maximum number of RAU's (extension capability)	22
Number of flexible inputs (analog or digital) per RAU	128
Analog: resolution of analog/digital conversion, bit	8
Discrete: number of inputs addressable as group	16
Number of serial pulse code modulation inputs per RAU	4
Clock rate, Mb/sec	1
Maximum number of words transferred per sample	32
Word lengths, bit	17
Maximum basic sampling rate, Hz	100
Data rate of transfer RAU/computer (including overhead), Mb/sec	1
Wideband scientific data	
Number of experiment channels of the high rate multiplexer (HRM)	16
Minimum data rate of HRM input channels, kb/sec	64
Maximum data rate of HRM input channels, Mb/sec	16
Number of closed circuit television video input channels	1
Number of 4.2-MHz analog channels	1
Data transmission to ground	
Nominal data rate for housekeeping and low rate scientific data from subsystem and experiment computer, kb/sec	64
Maximum data rate for wideband scientific data (via TDRSS), Mb/sec	50
Maximum data rate of high rate digital recorder (HRDR) bridging TDRSS noncoverage periods, Mb/sec	32
Storage capability of HRDR, bit	3.6×10^{10}
Payload command capability	
Telecommand rate from ground via Orbiter, kb/sec	2
Number of on/off command outputs per RAU	64
Number of serial pulse code modulation command channels per RAU	4
Clock rate, Mb/sec	1
Maximum number of words per command	32
Word length (including parity bit), bit	17
Payload data processing and displays	
Data processing:	
Word length, bit	16
Speed (Gibson mix), operations/sec	350 000
Floating point arithmetic, bit	32 (24+8)
Mass memory, Mbit	131
Display: alphanumerical display screen (tri-color diagonal, in. (cm)	12 (30.5)

allotted on dedicated or mixed missions. The pallet-alone configuration can be provided with Spacelab power and/or command and data handling resources only when and if surplus capability exists on a mission basis. Communications with NASA ground stations is through the Orbiter's communications system with up to 64 kbps of data transmitted. This mode interleaves data with the Shuttle operations telemetry. Selected portions can be displaced on the aft flight deck control panel (Figure A-11) or in the Spacelab module. Experiment data and voice transmissions will be recorded on the operations recorder when selected. In addition, up to 50 Mbps of data can be transmitted to the ground via the Tracking Data Relay Satellite System (TDRSS).

A.2.2 Crew

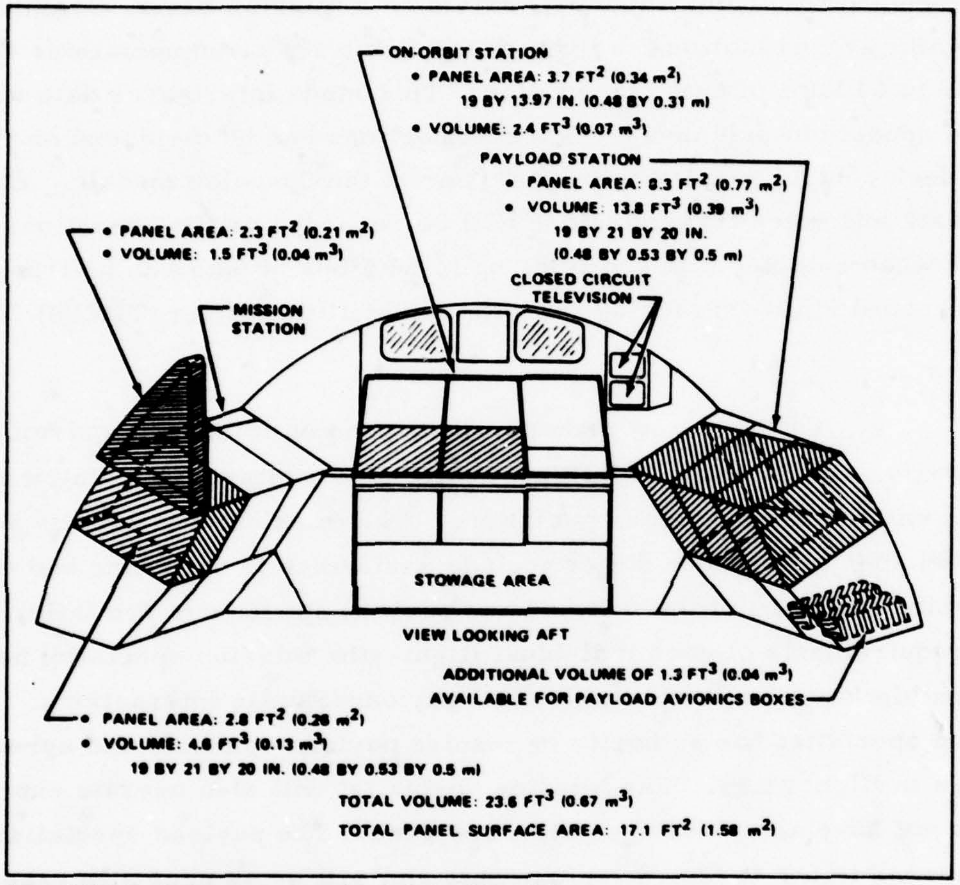
Orbiter crew makeup will depend on mission requirements, complexity, and duration. Each crew will have a mission specialist and may include one or more payload specialists. The mission specialist is a pilot-qualified specialist whose duties include assistance in operating and managing the Orbiter. Duties of the mission and payload specialists are tailored to meet requirements of each individual flight--the mission specialist being responsible for coordination of overall payload/Shuttle interactions. The mission specialist has authority to resolve payload conflicts and agree to changes in flight plans. The Mission Specialist will also operate experiments that do not have a payload specialist assigned. The payload specialist will be responsible for assigned experiments and will be an expert in experiment design and operation.

Capability for EVA is available on every Space Shuttle flight. Payload EVA falls into three categories:

a. Planned before launch in order to complete mission objective,

b. Unscheduled but decided upon during a flight in order to achieve payload operation success or advance overall mission accomplishments, and

c. Contingency measures necessary to get any payload items out of the way of the cargo bay doors.



Area available for payload equipment or controls in the Orbiter aft flight deck.

Figure A-11. Area Available for Payload Equipment or Controls in the Orbiter Aft Flight Deck

Equipment and consumables required for unscheduled and contingency EVA's are included on every Orbiter flight. Planned payload EVA is a user option.

Standard tools, tethers, restraints, and portable work stations for EVA are part of the Orbiter baseline support equipment inventory. The experimenter can make use of standard EVA support hardware to minimize crew training, operational requirements, and cost.

APPENDIX B

STP EXPERIMENT REQUIREMENTS

B.1 PRESENT EXPERIMENTS

As experimenters and project offices become more aware of the STS and its related subsystems, more of an effort will be made to utilize them to meet experimental needs. There are many differences between the approaches to planning experiments for expendable satellites and for the Shuttle. These differences will allow experiments to be planned in new and less restrictive ways. The present STP pool of experiments reflects the growing awareness of this fact on the part of experimenters. For example, during the last year there has been a transition from only a few Shuttle related experiments (four LDEF and HIRAD) to 10 additional ones which are designed expressly for operation with the Shuttle. These are HIRISE, Talon Gold, BMD, LASSII, Far UV, SEPS, CIRRIS, SAGE, Optical Countermeasures, and HUP. In addition, approximately five other experiments are adaptable to Shuttle sortie flights. These are ROMS/P, PDMM, SEEP, Disturbed Ionosphere, and CI Spectrometer. Some of these (ROMS/P, SEEP, and CI Spectrometer) would require reflight simply to obtain the required large data base if they were not modified.

A summary of experiments (approved, awaiting approval and new) divided into sortie and free flyer modes is shown in Figure B-1. Table B-1 shows how special features of the Shuttle will be used by the sortie-flown experiments. About one-half of the experiments indicate a need for, or an advantage to, using a pointing system and a payload specialist. It is evident that the experimenters are just beginning to utilize the capabilities of the Shuttle, but they have begun. The STP will assist them in their endeavor to make full utilization of these capabilities.

B.2 PROJECTED EXPERIMENTS

The everchanging pattern of experiments designed for STP spaceflight will probably continue at an accelerated pace in the future.

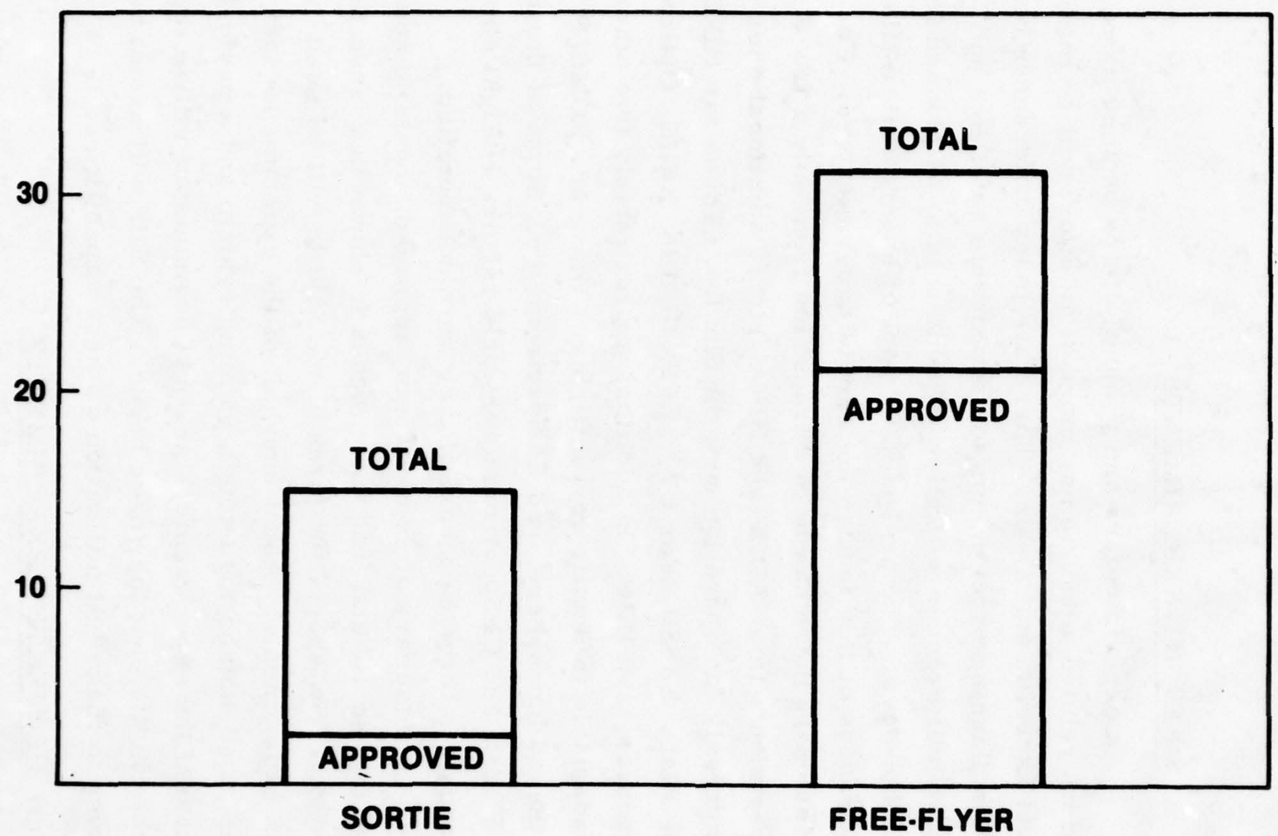


Figure B-1. STP Present and Potential Experiments

Table B-1. Experiment Utilization of Special Shuttle Features

Experiments	Features						
	Tethering	Tandem	Recovery	Special Deployment	Manned Operations	Pointing System	Space Lab
Approved							
Artificially Disturbed Ionosphere		X		X	X		
HIRAD					X	X	
CI Spectrometer							
Awaiting Approval							
Talon Gold				X	X		?
HIRISE					X	X	
BMD Target Measurement				X	X		
ROMS/P				X	X		
LASSII		X	X	X	X		
SEEP							
Far UV					X	X	
SEPS				X	X		
CIRRIS (EIRE Renamed)					X	X	
SAGE					X	X	
HUP					X	X	
New							
PDMM				X	X		
Optical Countermeasures				X	X		
TABS	X			X	X		

The impetus of new technology and goals, coupled with the STS capabilities discussed in Sections 2.0 and 3.0, provides vastly wider opportunities than ever before. The STP will try to determine the nature of experiments that DoD will need in the future so it can provide the necessary services for the experiments. Preliminary analyses indicate some interesting results as shown in the following.

B.2.1 Large Space Structures

Large structures are currently under active study by the DoD, NASA, and numerous contractors. These have many potential uses, including space stations, laser systems, communications systems, space-based radar, solar-collectors, and other passive optical systems. It is expected that on-orbit deployment and/or assembly tests will be conducted through STP scaled-down experiments. The presence of a payload specialist will be required to assist in the deployment or on-orbit assembly. The sizes expected may preclude the use of the Orbiter for deployment, and thus a tethered system looks attractive. Also a tether can assist with the temporary stabilization of the sections prior to assembly and function as a crane to transfer the structure into higher or lower orbits for further test.

B.2.2 Tandem Operations

Talon Gold and LASSII are current examples of tandem operations, using the Shuttle and a subsatellite or tethered package for interactive or bistatic experiments that are expected to grow in importance. As in the above examples, the two areas of interest involve both prototype systems tests and research type experiments. In the former category we can note laser systems for communications or damage, charged particle devices and accelerators, and radar or microwave systems operating in the bistatic mode. The more research oriented payloads include wave-particle interaction and trapped particle experiments for studies of the radiation belts and means for control of ionization phenomena; chemical releases for

studies of lower altitude dynamics, turbulence, ionospheric instabilities, or remote detection schemes; and in-situ instrumentation for examining spatial and temporal characteristics of natural and artificial disturbances.

Another use for a subsatellite or tethered package may revolve around the need to remove a payload from the Shuttle to avoid adverse influence on the Orbiter of EMI, system generated EMP, x-rays, high energy particles, or dangerous/toxic gas venting or releases generated by some payloads. As was noted earlier, large structures may also need to be removed from the Shuttle. This safety/environmental issue is important, particularly in the Shuttle era due to crew presence, and the potential conflicting requirements of many payloads closely spaced in the Orbiter bay.

B.2.3 Long Term Exposure to the Space Environment

The importance of survivability in space for military systems indicates that new technology materials, components, and even subsystems will be needed. The items to be tested extend over a very wide range. The LDEF for such experiments over extended time intervals may utilize telemetry links to provide the desired information so that recovery may not be necessary, or if it is, it could be undertaken after the suitable exposure conditions (as monitored by telemetry) were met. There is also a need for the LDEF type facility to be placed in higher orbits, which are more suitable for radiation damage tests (1500 nmi for the inner belt, for example). Much of this effort overlaps NASA interests so it is not clear to what extent the number of STP experiments would increase.

B.2.4 Optical Systems

Optical systems extending from the vacuum ultraviolet (VUV) to the long wavelength infrared (LWIR) for surveillance and remote probing of the earth, near earth space, and deep space will include both active (laser) and passive systems. For the infrared, new types of coolers will require testing. Perhaps thermoelectric refrigerators, which have the

advantages of operating from thermal energy and having no moving parts, may offer the required performance with longer life. New passive techniques for cooling may replace many active systems under development. Some passive optical systems are expected to require attitude control systems capable of high pointing accuracy, low drift and jitter, and very small settling times for rapid step-stare sequences. Signatures of some spacecraft systems will need to be reduced, suggesting the possibility of power generated by nuclear reactors, which can be shut off except when needed. Isotope power systems, such as Dynamic Power System, have the disadvantage of generating heat continuously.

B.2.5 Safety Issues

Large deployable systems, storage and tests of new liquid propellants, high powered lasers, deployable-retractable packages on booms, isotope or nuclear systems, and contamination of surfaces or systems from EMI, EMP, energetic particles, or chemical releases/venting present potential hazards that will require special safety impact assessments and potential scheduling problems. Survivability and reliability emphasis on operational systems by the DoD are expected to translate to longer space tests for some demonstration systems or components of the type flown by the STP.

B.2.6 Materials Processing in Space

Testing in space will be performed by a number of generic experiments as identified in an STS utilization study performed for the STP (Ref. B-1). Although many possible experiments were identified, there was only sufficient information on two for an experiment assessment. Although the DoD is expected to benefit materially from such testing in space, NASA is taking the lead with the development of a multipurpose fluid phenomena facility, multipurpose furnace, float zone refiner/crystal growth, and containerless inserts. These facilities will allow a wide range of techniques to be utilized for developing new materials and techniques for quality

materials. DoD uses, such as high purity composites for special thermal properties and strength for large space structures, or high purity crystals for semiconductor elements, laser rods, and solid state switches, are too numerous to provide a representative list. Whether the DoD will depend totally or partially on the NASA lead in this area is unknown. In any event, potential experimenters working along these lines will undoubtedly utilize NASA facilities.

A brief qualitative summary of possible projected needs, contrasted with present needs for experiments, based on the foregoing considerations, is presented in Table B-2. Some changes toward greater dependence on the various Shuttle capabilities can be noted.

Table B-2. Operational Mode Trends

Operational Mode	Current Need	Projected Need
Manned Operation	Weak	Moderate
Sortie	Moderate	Strong
Multi-Sortie	Weak	Moderate
Tethering	None	Weak
Recovery	Weak	Moderate
Tandem Operation	Weak	Moderate

APPENDIX C

STP COORDINATION WITH EXPERIMENTERS AND NASA

Among the many activities carried out in the past for coordination with the experimenters and NASA toward Shuttle utilization, the following are cited:

C.1 COMPLETED COORDINATION

C.1.1 1974 - 1977

STP maintained a dialogue and coordination with NASA Hq, Marshall Spaceflight Center, and Johnson Spaceflight Center to fly an STP payload on one Orbital Flight Test Mission, which led to the Memorandum of Agreement for OFT-6 signed in April 1977.

C.1.2 February 1975

STP had Dr. Fred Morse of Aerospace visit DoD laboratories to inform experimenters of Shuttle capabilities and to stimulate Shuttle experiments.

C.1.3 October 1975

STP conducted a Shuttle Utilization Conference held at The Aerospace Corporation to inform DoD R&D experimenters and industry of the Shuttle facilities, to introduce the STP standard satellite concept, and to stimulate experimenters to "think Shuttle".

C.1.4 October 1975

In August 1975 STP formally requested DoD agencies to submit potential Shuttle experiments. More than a dozen new experiment concepts were received and were discussed at the October 1975 Conference.

C.1.5 June 1976

STP responded to NASA Spacelab I Announcement of Opportunity and proposed three experiments. Unfortunately, all three were rejected by NASA.

C.1.6 August 1976

The second Shuttle Utilization conference was held at the Navy Research Laboratory (NRL), again for the purpose of introducing the various Shuttle facilities to the experiment community.

C.1.7 July - November 1976

STP contracted with TRW for a Spacelab Utilization Study that identified integration tasks and spaceborne equipment required. The need for a pointing system and a test rack was identified.

C.1.8 November 1976

STP negotiated a Memorandum of Agreement that was officially signed between DoD and NASA to fly payloads on the first Long Duration Exposure Facility (LDEF I). STP now has four payloads approved for this mission.

C.1.9 December 1976

STP had obtained an STS/STP mixed payload study, performed by Rockwell International, to investigate the feasibility of integrating various STP payload configurations with DoD payloads and with non-DoD payloads in STS missions. Nearly 50 percent of the then-existing STS missions were identified as having usable payload-bay length and weight margins for shared flights.

C.1.10 July - November 1977

STP contracted with TRW for a Shuttle Utilization study (Ref. B-1). Five regional meetings were conducted during which the STP

role and the Shuttle facilities were again briefed to experimenters. More than three dozen new experiments were stimulated. Some of them are included in the TRW overall assessment as to their suitability for Sortie missions.

C.1.11 August 1977 - Current

STP reactivated a suspended effort, which began in spring 1976, to establish a Memorandum of Agreement with NASA Hq for STP to fly missions on non-DoD Spacelab flights. Current effort will continue until a Memorandum of Agreement is signed.

C.1.12 September 1977

STP held a first meeting with NASA at Goddard Spaceflight Center on the so-called "Getaway-Special" (see Appendix A). This is for payloads that weigh less than 200 lb and occupy less than 5 ft^3. The dialogue will continue.

C.1.13 July - December 1977

STP contracted with General Electric for a study of the Standard Test Rack (Ref. 2-5) subsystem requirements. This concept offers DoD expanded opportunities for sortie spaceflights of many experiments on a low-cost and quick-reaction basis.

C.1.14 January - June 1978

TRW and General Electric completed studies (Ref. 2-6 and 2-7) for STP to determine a cost-effective approach between the Standard Test Rack and the ESA 3-m pallet. Results of these studies formed an integral part of the Five Year Plan.

C.2 PLANNED COORDINATION

The STP will continue to maintain coordinations and conduct studies with the goal of achieving utilization of the Shuttle capabilities. Some specific avenues of coordinating with the experimenters and NASA are presented in the following:

C.2.1 Annual Briefings

STP will continue annual meetings with the experimenters to discuss STP plans and the direction of future experiments. This could take the form of regional meetings as was done in 1977 or a general conference as was done in 1975 and 1976. STP found the regional meetings productive because they provided a relaxed atmosphere for information exchange with the experimenters. The STP Five Year Plan might be the topic of the next briefing.

C.2.2 Newsletter

A year ago a newsletter was initiated to inform experimenters of what was going on in STP. Quarterly status reports were used as the vehicle to include selected planning activities. This approach will be studied for amplification to cover a broader spectrum of activities and to make a section of the quarterly status report truly a newsletter.

C.2.3 Shuttle Payload Requirements Document

Several years ago STP instigated a Payload Requirements Document that was distributed to the experimenters after their payloads were selected for flights. This document provides guidance to the experimenters on test requirements and design parameters for ready interface with the spacecraft. It also delineates review and data requirements that the experimenters must meet to support the spacecraft contractor. This document was recently updated to include additional Shuttle requirements for free-flyers. A second document is planned, which will provide guidance to experiment design for sortie experiments on the Shuttle. Based on experience, STP believes that such a document will greatly facilitate experiment design, fabrication, and test prior to interface with STP hardware. Both documents will be sent to experimenters in advance of experiment selection for flight.

C.2.4 Form 1721 Revision

To meet the needs of Shuttle era operation, the Form 1721 will be revised. The revision will reflect the requirements for using the capability

of the Shuttle system and the operational concepts now made available. For example, while filling out the revised form the experimenter will be asked to address the options of sortie, tethered, or free-flying missions and to identify tasks to be performed by a payload specialist. The new form will be slanted toward encouraging experimenters to fully utilize the Shuttle capabilities and to coordinate with STP prior to the formal Form 1721 submission. Pre-submission coordination should be made mandatory so that STP and the experimenters will have an opportunity to consider trade-offs during the experiment concept formulation stage. Coordination on revision of Form 1721 with the Analytic Services Corporation (ANSER) will be maintained.

C.2.5 Review Current Experiments

Experimenters who have experiments on the current STP list (approved or to be approved) will be informed of the STP Five Year Plan and requested to re-think their experiments. Reconfiguration of experiments to more fully utilize the Shuttle capabilities, particularly sortie flight and astronaut participation, are desired.

C.2.6 Post-Flight "Lessons-Learned" Meeting

STP will evaluate the advisability for conducting "lessons-learned" meetings at an appropriate time following each space flight (including P78-1, P78-2, P80-1, P80-2 and S80-1). The purpose of these meetings will be to examine potential improvements to the total operations, leading to cost savings, and have the experimenters present results and follow-on potential experiments.

C.2.7 Spacelab Memorandum of Agreement

STP will continue to directly negotiate with NASA Hq on the Memorandum of Agreement for flying STP payloads on NASA Spacelab flights. Discussions so far indicate that NASA is agreeable to the DoD desire of having its payloads exempted from the NASA payload selection process and to reserve space and services for two flights a year.

C. 2.8 "Getaway Special" Memorandum of Agreement

During early discussions between STP and NASA, a workable concept emerged that would be mutually beneficial to NASA and DoD. This concept would allow STP to make 10 to 12 space reservations without deposit and would allow some of the NASA-collected "Getaway-Special" payloads to be flown on dedicated DoD Shuttle flights if compatible. Negotiations are expected to be complete sometime in FY 1979.

APPENDIX D

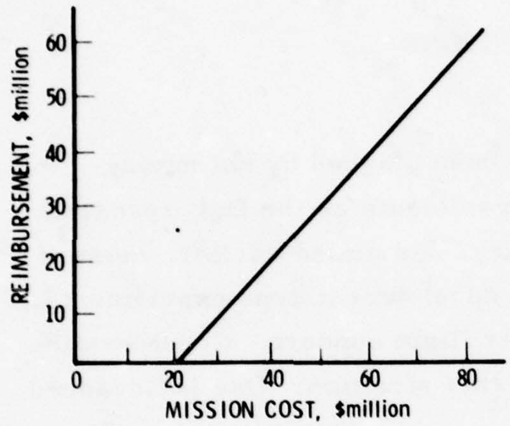
COST-SHARING OPTIONS

For quite some time STP has been plagued by not having sufficient funds to support as many space experiments as the DoD research and development community deemed necessary. As stated earlier, most of the STP funds are expended to support large development-type experiments. As a result, all experiments do not get timely flight support. Consideration has been given to various ways of improving this situation. One is advanced here, namely, STP/sponsor cost sharing.

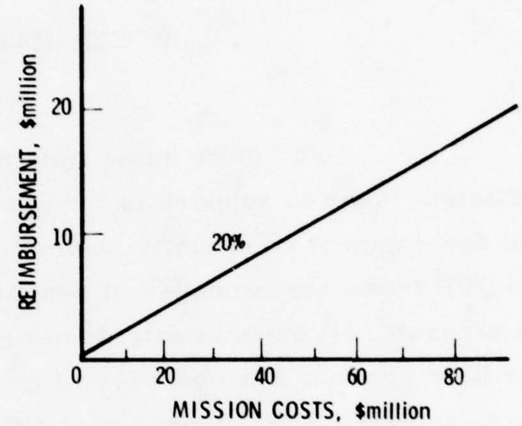
Basically, the idea is to have the experiment sponsor share part of the flight cost with STP, thus allowing STP to support more experiments. Currently, under AF Manual 80-2, the experiment sponsor reimburses STP costs associated with experiment-peculiar items that are above the standard services normally provided by STP. One example is the 6-kW solar array required to support the SIRE experiment. In this case, the SIRE experiment program office will reimburse STP for the cost of procuring that solar array. In the case of the MSP/Mini-HALO mission, the experimenters are responsible for the X-band transmitter. They also have been informed through planning discussions that in the event the experiment package is overweight, and a third propulsion stage is required above the two-stage IUS (inertial upper stage), the experimenters are responsible for the additional cost. Such a policy is still a valid and sound one. Additionally, there could be other cost-sharing options. All the options advanced to date, including the one already set forth in AF Manual 80-2, are discussed in the following. These options are diagrammed in Figure D-1.

D.1 OPTION A

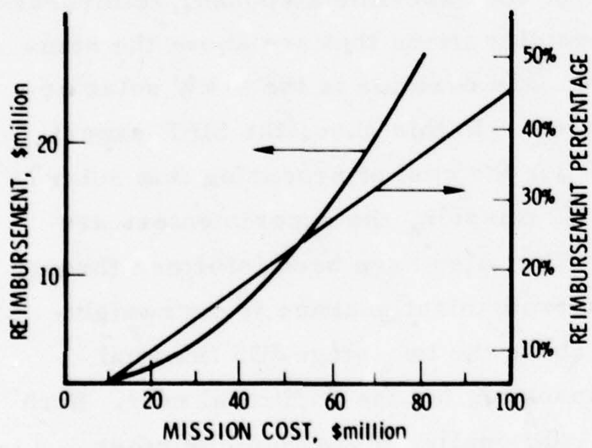
STP budgets no more than a fixed dollar amount for any given mission (e.g., \$20 million) and the experiment sponsors reimburse STP any



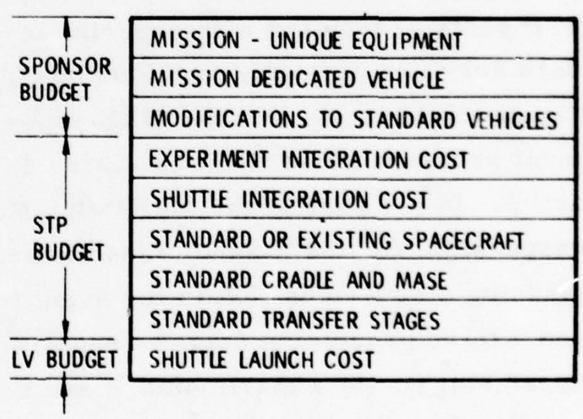
OPTION A: STP BUDGETS NO MORE THAN A FIXED DOLLAR AMOUNT FOR EACH MISSION (e.g. $20M). SPONSOR REIMBURSES STP ANY AMOUNT ABOVE THAT



OPTION B: SPONSOR REIMBURSES STP A FIXED PERCENTAGE OF MISSION COST (e.g. 20%)



OPTION C: SPONSOR REIMBURSE STP ACCORDING TO A GRADUATED PERCENTAGE SCALE (e.g. $\frac{R}{X} = \frac{X-10}{200}$, WHERE R = REIMBURSEMENT, X = MISSION COST)



OPTION D: STP PROVIDES STANDARD SERVICES, SPONSOR REIMBURSES STP ANY SERVICES REQUIRED ABOVE THE STANDARD

Figure D-1. Cost-Sharing Options

amount above that. Sponsors of a multiple-experiment mission share the reimbursement on the basis of an agreed-upon pro rata criteria composed of weight, power, telemetry, and attitude control requirements. Once a mission is on contract and its cost known, the reimbursement can be worked out by STP. Each sponsor is responsible for his share of the reimbursement, and any over-run during the course of the mission integration will be borne by STP. Missions costing less than $20 million do not require reimbursement from the sponsors. The $20 million figure is subject to further discussion.

This option encourages low-cost missions and it is straightforward to apply. The drawback is that it imposes an extremely severe penalty on expensive missions. For instance, the MSP/Mini-HALO mission is estimated at $76 million and the experimenters would be required to reimburse STP $56 million -- a considerable penalty.

D.2 OPTION B

Experiment sponsors reimburse STP a fixed percentage of mission cost (e.g., 20 percent). Again, sponsors of a multiple-experiment mission share the reimbursement according to some pro rata criteria. After the sponsors reimburse STP the prorated share at the beginning of the integration contract, STP would be responsible for over-runs, if incurred. The 20 percent figure is subject to further discussion.

This option does not particularly encourage low-cost missions since experimenters are obligated to a fixed percentage, but it is straightforward to apply.

D.3 OPTION C

Experiment sponsors reimburse STP according to a graduated percentage scale (e.g., $\frac{R}{X} = \frac{X-10}{200}$, where R = reimbursement, X = mission cost). Again the sharing of the reimbursement among all sponsors of a mission and the over-run policy depicted in Option A would apply. The scale used here is subject to further discussion, but the concept is of essence in this discussion. The $10 million cutoff is also arbitrary.

This option encourages low-cost missions because of the increased percentage of reimbursement for increased mission cost. It is simple to apply but it penalizes the sponsors of the smaller, secondary experiments since they are forced to reimburse STP a higher percentage when their experiments are flown with a more costly primary experiment.

D.4 OPTION D

STP provides standard services and the experiment sponsors reimburse STP for any services above the standard. Here, the STP must first define and publish the standard services so that the experiment sponsors know what they are in advance and take advantage of them during the experiment definition phase. A strawman list is illustrated in Figure D-1. This idea is equivalent to that already set forth in AF Manual 80-2, only somewhat extended and defined in finer details.

This option encourages the use of standard equipment and services, thereby reducing mission cost. It is more flexible than the other three options in that it points out areas where the experiment sponsor can effectively reduce the reimbursement since it is directly related to specific equipment and service. It also has the advantage that the small, secondary experiments can possibly fly free of any reimbursement. However, it is more complex to apply since it requires fairly extensive discussions with the sponsors.

All these options need to be carefully analyzed within STP and at the AFSC and AFRDS levels before any one is officially adopted as a policy. Only the policy set forth in AF Manual 80-2 was used to obtain cost estimates for the Five Year Plan.

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GLOSSARY

AFSCF	Air Force Satellite Control Facility
AFWL	Air Force Weapons Laboratory
ANSER	Analytic Services Corporation
ASPS	Annular Suspension and Pointing System
BITE	Built-in Test Equipment
BMD	Ballistic Missile Defense (experiment)
CIRRIS	Cryogenic Infrared Radiometer Interferometer Satellite (experiment)
CI Spectrometer	Constant Impulse Spectrometer (experiment)
CIU	*Communication Interface Unit*
COSMo	Cost Optimized Service Module
CRL	Air Force Cambridge Research Laboratories (now Air Force Geophysics Laboratories)
CRT	cathode ray tube
CSE	common support equipment
DMSP	Defense Meteorological Satellite Program
DSCS	Defense Satellite Communications System
Dismedia	Disturbed Media (experiment)
EECC	Experiment Exposure Control Canister
E^2S^2	Environmental Effects on Space Systems (experiment)
EMI	electromagnetic interference
EMP	electromagnetic pulse
EPDS	Electrical Power and Data System

ESA	European Space Agency
EVA	extravehicular activity
Free-Flyer	a self-sufficient satellite launched by the Shuttle and separated from it once on orbit
Getaway-Special	NASA canister that holds small self-contained payloads, with limited Shuttle services, flown attached within the Orbiter
GPS	Global Positioning System
HIRAD	High Energy Radiation Monitor (experiment)
HUP	Horizontal ultraviolet Program (experiment)
IPS	instrument pointing subsystem
IUS	Inertial Upper Stage
JPL	Jet Propulsion Laboratory
KSC	Kennedy Space Center
LASSII	Low Altitude Satellite Study of Ionospheric Irregularities (experiment)
LDEF	Long Duration Exposure Facility
LES	Lincoln (Laboratory) Experimental Satellite
LV	launch vehicle
MASE	manned aerospace support equipment
Mini-HALO	DARPA experiment based on HALO (High Altitude Large Optics) technologies
MMS	Multimission Modular Spacecraft
MSP	Mosaic Sensor Program (experiment)
NASA	National Aeronautics and Space Agency
NRL	Navy Research Laboratory
OA/RCS	Orbit Adjust and Reaction Control System

O&C	Operations and Checkout (Building)
OFT	Orbiter Processing Facility
OMS	Orbit Maneuver System
OPF	Orbiter Processing Facility
PACSAT	Passive Communications Satellite (experiment)
PDMM	Pulsed Doppler Map Matching (experiment)
PCR	Payload Changeout Room
PIC	Payload Integration Contractor
PIE-2	Plasma Interaction Experiment-2
RCS	Reaction Control System
RMS	Remote Manipulator System
ROMS/P	Remote Ocean Surface Measuring Sensor/Passive Microwave Sensor (experiment)
RTS	remote tracking station
SAGE	Spatial Airglow Experiment
SAMTEC	Space and Missile Test Center (SAMSO) (formerly AFWTR)
SCATHA	Spacecraft Charging at High Altitudes (experiment)
SCS	Satellite Control Section (spacecraft)
SEEP	Stimulated Emission of Energies Particles (experiment)
SEPS	Shuttle Effects on Plasmas in Space (experiment)
SGLS	Space Ground Link Subsystem
SINC	Spacecraft Integration Contractor
SIRE	Satellite Infrared Experiment

Sortie	short duration Shuttle launched space flight where the satellite remains attached to the Orbiter.
STDN	Space Tracking and Data Network (NASA)
STP	Space Test Program
STR	Standard Test Rack
STS	Space Transportation System
TABS	Target and Background Satellite (experiment)
TDRSS	Tracking and Data Relay Satellite System
TT&C	telemetry, tracking, and command
TSS	Tethered Satellite System
UARS	Upper Atmosphere Research Satellite
VAF	Vehicle Assembly Facility
VUV	vacuum ultraviolet

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Attn: AFRDQPN
RDQSM, Maj McLaren
RDS
RDS, JESCQ
RDSL, Maj Wilde

SAMTEC/ROPP
Vandenberg Air Force Base, CA 94337

6595 Space Test Group
Vandenberg Air Force Base, CA 93437
Attn: PJS

Defense Advanced Research Project Agency
1400 Wilson Blvd.
Arlington, VA 22209
Attn: NMRD, Lt Col G. Budin

Chief of Naval Research
800 N. Quincy St.
Arlington, VA 22217
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Department of the Navy
Washington, DC 20350
Attn: OP 98631, Lt Cmdr C. Bachmer

Commander
Naval Electronics Systems Command
Washington, DC 20360
Attn: PME106, RADM, G. Yowell
ELEX 03, Capt J. Wheeler

Commander
Naval Research Laboratory
4555 Overlook Ave., SW
Washington, DC 20375
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Code 7000, E. Caruthers
Code 7006, V. Noble
Code 7020, J. Adams
Code 7120, T. Chubb
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Naval Air Test Center
Patuxent River, MD 20670
Attn: W. Rupp

Commander
Naval Underwater Systems Center
Newport, RI 02840
Attn: TA12, S. Turner

Commander
Naval Ocean Systems
San Diego, CA 92152
Attn: Code 2020, J. Richter

Commander
Naval Air Systems Command
Washington, DC 20360
Attn: AIR 503H, T. Smith
AIR 360, F. Lueking
AIR 370, T. Czuba

Spacelab Payload Project Office
NASA Marshall Spaceflight Center,
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Washington, DC 20546
Attn: MO, Lt Col Ojalehto,
Maj G. Janson
ST-5, H. Glaser

NASA Langley Research Center
Hampton, VA 23665
Attn: AFSC Liaison Office, Chief
J. DeBatista

NASA Goddard Space Flight Center
Greenbelt, MD 20771
Attn: Code 601, L. Dubach

NASA J. F. Kennedy Space Center
Western Test Range Operations Division
P.O. Box 425
Lompoc, CA 93436

NASA J. F. Kennedy Space Center
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